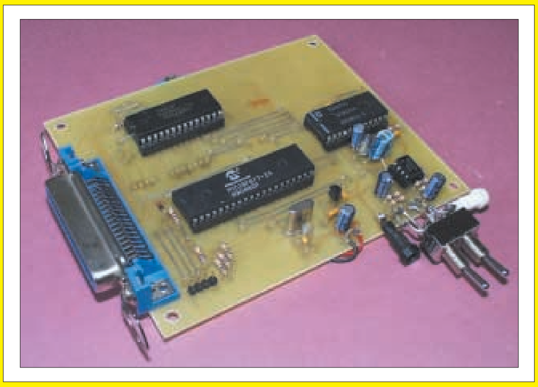
THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

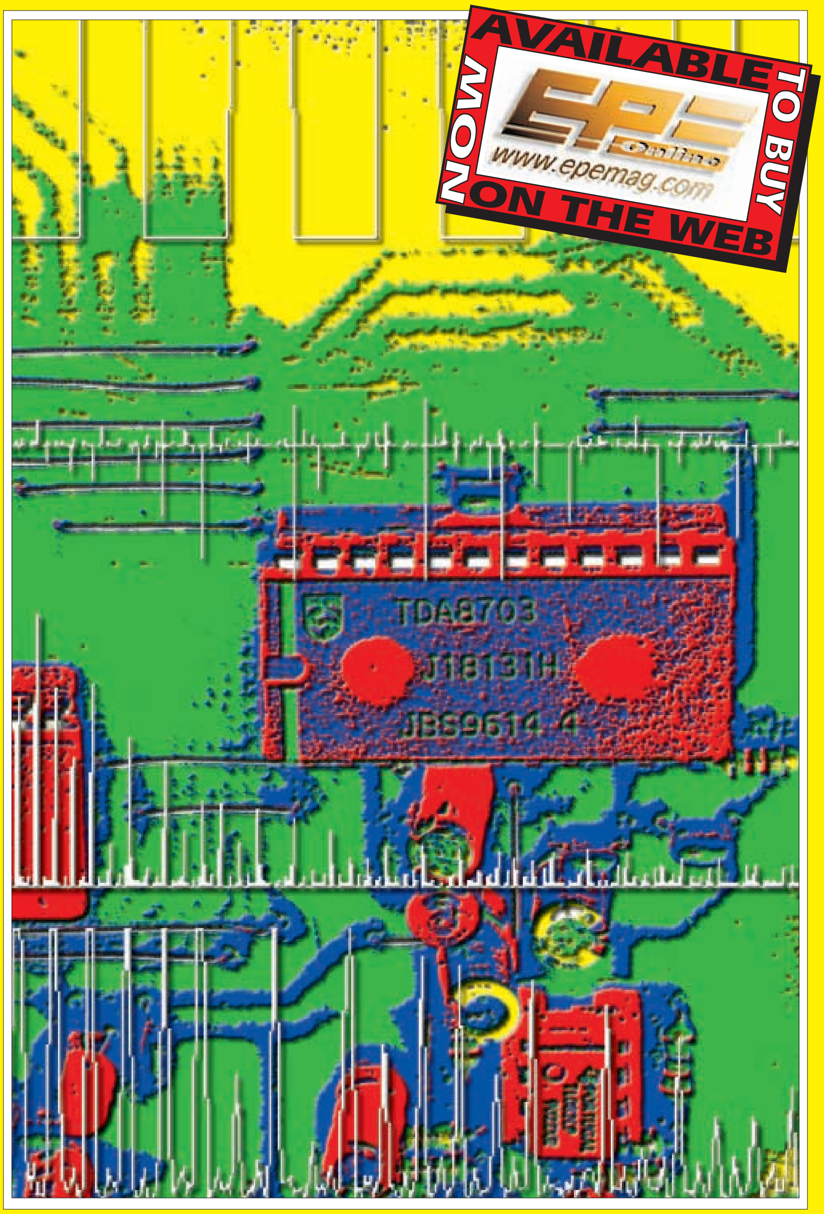
EVERYDAY PRACTICAL ELECTRONICS

Vol.31 No.2

CAN $6.99/US $4.95

PIC SPECTRUM ANALYSER
Analyse waveforms on your PC





GUITAR AMP
Easy to build practice amp

HT POWER SUPPLY
For battery valve radios

PLUS

RUSSIAN SPACE SHUTTLE REVISITED
Will Buran fly again?

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PROJECTS . . . THEORY . . . NEWS . . .
COMMENTS . . . POPULAR FEATURES . . .

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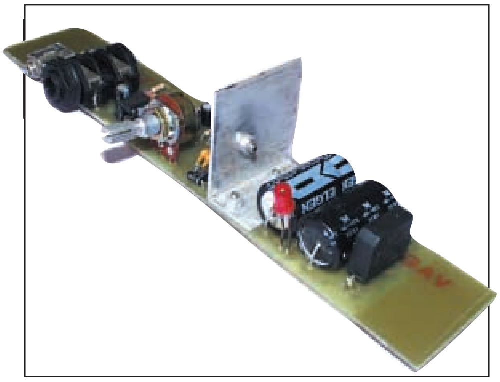
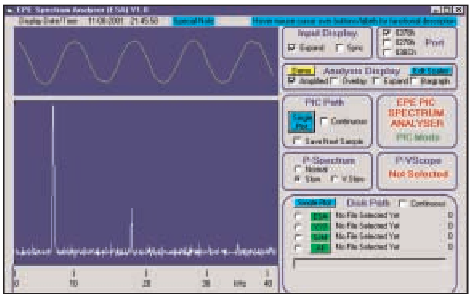
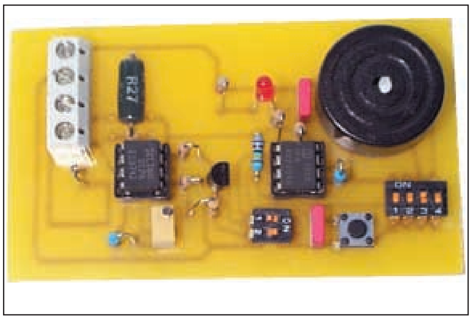


Projects and Circuits



Series and Features

Regulars and Services



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Our March 2002 issue will be published on Thursday, 14 February 2002. See page 75 for details

NEXT MONTH

PIC VIRUS ZAPPER

This simple PIC-controlled unit is based on the work of Dr Hulda Regehr Clark, who claims that it is a cure for many diseases. Enthusiasts for the device claim that it is effective in dealing with most viral infections, some going so far as to claim they haven't had even a common cold in years! Apparently they either "zap" every few days as a general precaution or they use it at the first signs of a cold or other illness before it has had time to take hold properly. Sounds worth trying at least, but the author is still waiting for the onset of a cold in order to experiment!

This easy-to-build inexpensive project will allow anyone to try the idea for themselves, it provides the suggested electronic output plus the timing for each "treatment". Maybe EPE *readers can prove or disprove the theory.*

RELATIVE HUMIDITY METER

This Relative Humidity (RH) Meter (hygrometer) uses a new capacitive RH sensing element to give an accurate measure of the relative humidity of air. The sensor contains on-chip integrated signal processing to give a d.c. output proportional to RH. The element is laser trimmed to a preset output span so that a simple but very effective RH meter can be produced without the need for calibration in standard atmospheres.

The traditional analogue meter readout is a visually comfortable way of representing the ambient RH. But a ground referenced analogue output is provided for PC or PIC recording, processing or data logging.

MINI-ENIGMA

The Mini-Enigma was borne out of an interest in both encryption techniques and PIC microprocessors. The initial idea was to create a PIC-based unit, which would enable the user to type in a brief text message, which can then be encrypted at the press of a button. By the same token, if the encrypted message was typed into the unit it could be de-coded into the original text message. This enables two people to send secret messages to each other and be safe in the knowledge that the text is very difficult to decipher without using the unit.

The unit also has the unique capability of being able to connect to a "match-box memory", which enables the user to download a message into the box, the information from the box can then be retrieved by the other person at a later time by using their Mini-Enigma unit.

PROGRAMMING PIC INTERRUPTS

How to use Interrupts successfully with your PIC programs. The Microchip PIC family of microcontrollers supports interrupts. However, relatively few of the projects published in EPE *to date have used interrupts.*

Programming a PIC to use interrupts is not completely straightforward (but then sometimes neither is programming a PIC to do anything!). There are some special considerations that need to be borne in mind.

This article gives a general introduction to the topic of writing PIC software to handle interrupts, with special reference to the PIC16x84 and PIC16F87x families, which are the most popular with hobbyists.

PLUS: TEACH-IN 2002, Part 5
AND ALL THE REGULAR FEATURES

NO ONE DOES IT BETTER

EVERYDAY PRACTICAL ELECTRONICS
INCORPORATING ELECTRONICS TODAY INTERNATIONAL

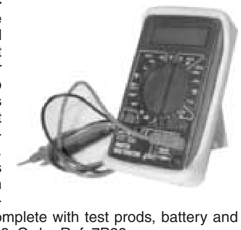
DON'T MISS AN ISSUE – PLACE YOUR ORDER NOW!
Demand is bound to be high

MARCH 2002 ISSUE ON SALE THURSDAY, FEBRUARY 14

£1 BARGAIN PACKS
Selected items

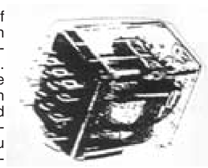
PIEZO ELECTRIC SOUNDER, also operates efficiently as a microphone. Approximately 30mm diameter, easily mountable, 2 for £1. Order Ref: 1084.
LIQUID CRYSTAL DISPLAY on p.c.b. with i.c.s etc. to drive it to give 2 rows of 8 figures or letters with data. Order Ref: 1085.
30A PANEL MOUNTING TOGGLE SWITCH. Double-pole. Order Ref: 166.
SUB MIN TOGGLE SWITCHES. Pack of 3. Order Ref: 214.
HIGH POWER 3in. SPEAKER (11W 8ohm). Order Ref: 246.
MEDIUM WAVE PERMEABILITY TUNER. It's almost a complete radio with circuit. Order Ref: 247.
HEATING ELEMENT, mains voltage 100W, brass encased. Order Ref: 8.
MAINS MOTOR with gearbox giving 1 rev per 24 hours. Order Ref: 89.
ROUND POINTER KNOBS for flatted ¼in. spindles. Pack of 10. Order Ref: 295.
REVERSING SWITCH. 20A double-pole or 40A single pole. Order Ref: 343.
LUMINOUS PUSH-ON PUSH-OFF SWITCHES. Pack of 3. Order Ref: 373.
SLIDE SWITCHES. Single pole changeover. Pack of 10. Order Ref: 1053.
PAXOLIN PANEL. Approximately 12in. x 12in. Order Ref: 1033.
CLOCKWORK MOTOR. Suitable for up to 6 hours. Order Ref: 1038.
TRANSISTOR DRIVER TRANSFORMER. Maker's ref. no. LT44, impedance ratio 20k ohm to 1k ohm; centre tapped, 50p. Order Ref: 1/23R4.
HIGH CURRENT RELAY, 12V d.c. or 24V a.c., operates changeover cocntacts. Order Ref: 1026.
3-CONTACT MICROSWITCHES, operated with slightest touch, pack of 2. Order Ref: 861.
HIVAC NUMICATOR TUBE, Hivac ref XN3. Order Ref: 865 or XN11 Order Ref: 866.
2IN. ROUND LOUDSPEAKERS. 50Ω coil. Pack of 2. Order Ref: 908.
5K POT, standard size with DP switch, good length ¼in. spindle, pack of 2. Order Ref: 11R24.
13A PLUG, fully legal with insulated legs, pack of 3. Order Ref: GR19.
OPTO-SWITCH on p.c.b., size 2in. x 1in., pack of 2. Order Ref: GR21.
COMPONENT MOUNTING PANEL, heavy paxolin 10in. x 2in., 32 pairs of brass pillars for soldering binding components. Order Ref: 7RC26.
HIGH AMP THYRISTOR, normal 2 contacts from top, heavy threaded fixing underneath, think amperage to be at least 25A, pack of 2. Order Ref: 7FC43.
BRIDGE RECTIFIER, ideal for 12V to 24V charger at 5A, pack of 2. Order Ref: 1070.
TEST PRODS FOR MULTIMETER with 4mm sockets. Good length flexible lead. Order Ref: D86.
LUMINOUS ROCKER SWITCH, approximately 30mm square, pack of 2. Order Ref: D64.
MES LAMPHOLDERS slide on to ¼in. tag, pack of 10. Order Ref: 1054.
HALL EFFECT DEVICES, mounted on small heatsink, pack of 2. Order Ref: 1022.
12V POLARISED RELAY, 2 changeover contacts. Order Ref: 1032.
PROJECT CASE, 95mm x 66mm x 23mm with removable lid held by 4 screws, pack of 2. Order Ref: 876.
LARGE MICROSWITCHES, 20mm x 6mm x 10mm, changeover contacts, pack of 2. Order Ref: 826.
COPPER CLAD PANELS, size 7in. x 4in., pack of 2. Order Ref: 973.
100M COIL OF CONNECTING WIRE. Order Ref: 685.
WHITE PROJECT BOX, 78mm x 115mm x 35mm. Order Ref: 106.
LEVER-OPERATED MICROSWITCHES, ex-equipment, batch tested, any faulty would be replaced, pack of 10. Order Ref: 755.
MAINS TRANSFORMER, 12V-0V-12V, 6W. Order Ref: 811.
QUARTZ LINEAR HEATING TUBES, 306W but 110V so would have to be joined in series, pack of 2. Order Ref: 907.
REELS INSULATION TAPE, pack of 5, several colours. Order Ref: 911.
LIGHTWEIGHT STEREO HEADPHONES. Order Ref: 989.
THERMOSTAT for ovens with ¼in. spindle to take control knob. Order Ref: 857.
MINI STEREO 1W AMP. Order Ref: 870.

SELLING WELL BUT STILL AVAILABLE



IT IS A DIGITAL MULTITESTER, complete with backrest to stand it and hands-free test prod holder. This tester measures d.c. volts up to 1,000 and a.c. volts up to 750; d.c. current up to 10A and resistance up to 2 megs. Also tests transistors and diodes and has an internal buzzer for continuity tests. Comes complete with test prods, battery and instructions. Price £6.99. Order Ref: 7P29.
INSULATION TESTER WITH MULTIMETER. Internally generates voltages which enable you to read insulation directly in megohms. The multimeter has four ranges: AC/DC volts, 3 ranges DC milliamps, 3 ranges resistance and 5 amp range. These instruments are ex-British Telecom but in very good condition, tested and guaranteed OK, probably cost at least £50 each, yours for only £7.50 with leads, carrying case £2 extra. Order Ref: 7.5P4.
REPAIRABLE METERS. We have some of the above testers but slightly faulty, not working on all ranges, should be repairable, we supply diagram, £3. Order Ref: 3P176.
PHILIPS 9in. MONITOR. Not cased, but it is in a frame for rack mounting. It is high resolution and was made to work with the IBM 'One per disk' computer. price £15. Order Ref: 15P1.
METAL CASE FOR 9in. MONITOR. Supplied as a flat pack, price £12. Order Ref: 12P3.
ANOTHER PROJECT CASE. Should be very suitable for a non-recognisable bug or similar hand-held device. It is 150mm long, 36mm wide and 15mm thick. Originally these were TV remote controls, price 2 for £1. Order Ref: 1068.
A MUCH LARGER PROJECT BOX. Size 216mm x 130mm x 85mm with lid and 4 screws. This is an ABS box which normally retails at around £6. All brand new, price £2.50. Order Ref: 2.5P28.
BT TELEPHONE EXTENSION WIRE. This is proper heavy duty cable for running around the skirting board when you want to make a permanent extension. Four cores properly colour coded, 25m length only £1. Order Ref: 1067.
HEAVY DUTY POT. Rated at 25W, this is 20 ohm resistance so it could be just right for speed controlling a d.c. motor or device or to contraol the output of a high current. Price £1. Order Ref: 1/33L1.
1mA PANEL METER. Approximately 80mm × 55mm, front engraved 0-100. Price £1.50 each. Order Ref: 1/16R2.
VERY THIN DRILLS. 12 assorted sizes vary between 0·6mm and 1·6mm. Price £1. Order Ref: 128.
EVEN THINNER DRILLS. 12 that vary between 0·1mm and 0·5mm. Price £1. Order Ref:129.
D.C. MOTOR WITH GEARBOX. Size 60mm long, 30mm diameter. Very powerful, operates off any voltage between 6V and 24V D.C. Speed at 6V is 200 rpm, speed controller available. Special price £3 each. Order Ref: 3P108.
FLASHING BEACON. Ideal for putting on a van, a tractor or any vehicle that should always be seen. Uses a Xenon tube and has an amber coloured dome. Separate fixing base is included so unit can be put away if desirable. Price £5. Order Ref: 5P267.
MOST USEFUL POWER SUPPLY. Rated at 9V 1A, this plugs into a 13A socket, is really nicely boxed. £2. Order Ref: 2P733.
MOTOR SPEED CONTROLLER. These are suitable for D.C. motors for voltages up to 12V and any power up to 1/6h.p. They reduce the speed by intermittent full voltage pulses so there should be no loss of power. In kit form these are £12. Order Ref: 12P34. Or made up and tested, £20. Order Ref: 20P39.
BALANCE ASSEMBLY KITS. Japanese made, when assembled ideal for chemical experiments, complete with tweezers and 6 weights 0·5 to 5 grams. Price £2. Order Ref: 2P44.
CYCLE LAMP BARGAIN. You can have 100 6V 0·2A MES bulbs for just £2.50 or 1,000 for £20. They are beautifully made, slightly larger than the standard 6·3V pilot bulb so they would be ideal for making displays for night lights and similar applications.
SOLDERING IRON, super mains powered with long-life ceramic element, heavy duty 40W for the extra special job, complete with plated wire stand and 245mm lead, £3. Order Ref: 3P221.
HIGH AMP THYRISTOR. Normal two contacts from the top and heavy threaded fixing underneath. We don't know the amperage of this but think it to be at least 25A. Price 50p each. Order Ref: 1/7RC43.
THREE LEVEL PRESSURE SWITCH. All 3 are low pressures and the switch could be blow-operated. With a suitable tubing these switches could control the level of liquid, etc., price £1. Order Ref: 67.
BREAKDOWN UNIT, Order Ref: BM41001. This is probably the most valuable breakdown unit that you have ever been offered. It contains the items specified below, just 2 of which are currently selling at £3.50 each. Other contents are:
Computer grade electrolytics, 330μF 250V DC, you get 4 of these. 4,700μF at 50V DC, you get 2 of these. 1,000μF at 16V DC, you get one of these, and 16A 250V double rocker switch, 115V to 250V selector switch. You also get a standard flat pin instrument socket, a 250V 5A bridge rectifier, 2 x 25A bridge rectifiers mounted on an aluminium heatsink but very easy to remove.
2 *NPN* power transistors ref. BUV47, currently listed by Maplins at £3.50 each, a power thyristor, Mullard ref. BTW69 or equivalent, listed at £3.
All the above parts are very easy to remove. 100s of other parts not so easy to remove, all this is yours for £5. Order Ref: 1/11R8.

RELAYS

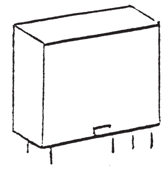


We have thousands of relays of various sorts in stock, so if you need anything special give us a ring. A few new ones that have just arrived are special in that they are plug-in and come complete with a special base which enables you to check voltages of connections of it without having to go underneath. We have 6 different types with varying coil voltages and contact arrangements.

Coil Voltage	Contacts	Price	Order Ref:
12V DC	4-pole changeover	£2.00	FR10
24V DC	2-pole changeover	£1.50	FR12
24V DC	4-pole changeover	£2.00	FR13
240V AC	1-pole changeover	£1.50	FR14
240V AC	4-pole changeover	£2.00	FR15

Prices include base

MINI POWER RELAYS
For p.c.b. mounting, size 28mm x 25mm x 12mm, all have 16A changeover contacts for up to 250V. Four versions available, they all look the same but have different coils:

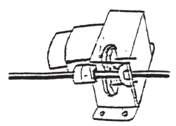


6V Order Ref: FR17
12V Order Ref: FR18
24V Order Ref: FR19
48V Order Ref: FR20
Price £1 each less 10% if ordered in quantities of 10, same or mixed values.

4 CIRCUIT 12V RELAY. Quite small, clear plastic enclosed and with plug-in tags, £1. Order Ref: 205N.
NOT MUCH BIGGER THAN AN OXO CUBE. Another relay just arrived is extra small with a 12V coil and 6A changeover contacts. It is sealed so it can be mounted in any position or on a p.c.b. Price 75p each, 10 for £6 or 100 for £50. Order Ref: FR16.
BIG POWER RELAY. These are open type fixed by screws into the threaded base. Made by Omron, their ref: MM4. These have 4 sets of 25A changeover contacts. The coil is operated by 50V AC or 24V DC, price £6. Order Ref: 6P.
SIMILAR RELAY but smaller and with only 2 sets of 25A changeover contacts. Coil voltage 24V DC, 50V AC, £4. Order Ref: 4P.
BIG POWER LATCHING RELAY. Again by Omron, their ref: MM2K. This looks like a double relay, one on top of the other. The bottom one has double-pole 20A changeover contacts. The top one has no contacts but when energised it will lock the lower relay either on or off depending on how it is set. Price £6. Order Ref: 6P.
RECHARGEABLE NICAD BATTERIES. AA size, 25p each, which is a real bargain considering many firms charge as much as £2 each. These are in packs of 10, coupled together with an output lead so are a 12V unit but easily divideable into 2 × 6V or 10 × 1·2V. £2.50 per pack, 10 packs for £25 including carriage. Order Ref: 2.5P34.

BUY ONE GET ONE FREE

ULTRASONIC MOVEMENT DETECTOR. Nicely cased, free standing, has internal alarm which can be silenced. Also has connections for external speaker or light. Price £10. Order Ref: 10P154.
CASED POWER SUPPLIES which, with a few small extra components and a bit of modifying, would give 12V at 10A. Originally £9.50 each, now 2 for £9.50. Order Ref: 9.5P4.
3-OCTAVE KEYBOARDS with piano size keys, brand new, previous price £9.50, now 2 for the price of one. Order Ref: 9.5P5.



1·5V-6V MOTOR WITH GEARBOX. Motor is mounted on the gearbox which has interchangeable gears giving a range of speeds and motor torques. Comes with full instructions for changing gears and calculating speeds, £7. Order Ref: 7P26.
MINI BLOWER HEATER. 1kW, ideal for under desk or airing cupboard, etc., needs only a simple mounting frame, price £5. Order Ref: 5P23.
IT IS VERY POWERFUL. In fact it is almost ¼h.p. and can be driven by a 12V battery, so one on each wheel would drive a go-kart and its passenger. Made by the famous Smiths company, this motor should give a good, long, trouble-free service. Offered at £12 each or if you order a pair, then you can have the pair for £20. Order Ref: 12P41.

TERMS

Send cash, PO, cheque or quote credit card number. If order under £25 and for heavy items add £4.50 carriage. If lightweight add postage which you think will cover.

J & N FACTORS
Pilgrim Works (Dept.E.E.)
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E-mail: jnfactors@aol.com

SIMPLE PIC PROGRAMMER

INCREDIBLE LOW PRICE! **Kit 857 £12.99**

INCLUDES 1-PIC16F84 CHIP SOFTWARE DISK, LEAD CONNECTOR, PROFESSIONAL PC BOARD & INSTRUCTIONS

Power Supply £3.99

EXTRA CHIPS:
PIC 16F84 £4.84

Based on February '96 EPE. Magenta designed PCB and kit. PCB with 'Reset' switch, Program switch, 5V regulator and test L.E.D.s, and connection points for access to all A and B port pins.

PIC 16C84 DISPLAY DRIVER

INCLUDES 1-PIC16F84 WITH DEMO PROGRAM SOFTWARE DISK, PCB, INSTRUCTIONS AND 16-CHARACTER 2-LINE
LCD DISPLAY

Kit 860 £19.99

Power Supply £3.99

FULL PROGRAM SOURCE CODE SUPPLIED – DEVELOP YOUR OWN APPLICATION!

Another super PIC project from Magenta. Supplied with PCB, industry standard 2-LINE × 16-character display, data, all components, and software to include in your own programs. Ideal development base for meters, terminals, calculators, counters, timers – Just waiting for your application!

PIC 16F84 MAINS POWER 4-CHANNEL CONTROLLER & LIGHT CHASER

- WITH PROGRAMMED 16F84 AND DISK WITH SOURCE CODE IN MPASM
- ZERO VOLT SWITCHING MULTIPLE CHASE PATTERNS
- OPTO ISOLATED 5 AMP OUTPUTS
- 12 KEYPAD CONTROL
- SPEED/DIMMING POT.
- HARD-FIRED TRIACS

Now features full 4-channel chaser software on DISK and pre-programmed PIC16F84 chip. Easily re-programmed for your own applications. Software source code is fully 'commented' so that it can be followed easily.

Kit 855 £39.95

LOTS OF OTHER APPLICATIONS

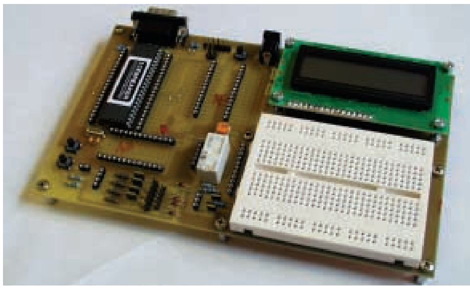
8-CHANNEL DATA LOGGER

NEW!

As featured in Aug./Sept. '99 *EPE*. Full kit with Magenta redesigned PCB – LCD fits directly on board. Use as Data Logger *or* as a test bed for many other 16F877 projects. Kit includes programmed chip, 8 EEPROMs, PCB, case and all components.

KIT 877 £49.95 inc. 8 × 256K EEPROMS

ICEBREAKER



PIC Real Time In-Circuit Emulator

- Icebreaker uses PIC16F877 in circuit debugger
- Links to Standard PC **Serial** Port (lead supplied)
- Windows™ (95+) Software included
- Works with MPASM and MPLAB Microchip software
- 16 x 2 L.C.D., Breadboard, Relay, I/O devices and patch leads supplied

As featured in March '00 *EPE*. Ideal for beginners AND advanced users.
Programs can be written, assembled, downloaded into the microcontroller and run at full speed (up to 20MHz), or one step at a time.
Full emulation means that all I/O ports respond exactly and immediately, reading and driving external hardware.
Features include: Reset; Halt on external pulse; Set Breakpoint; Examine and Change registers, EEPROM and program memory; Load program, Single Step with display of Status, W register, Program counter, and user selected 'Watch Window' registers.

KIT 900 . . . £34.99

POWER SUPPLY **£3.99** STEPPING MOTOR **£5.99**

EPE PIC TOOLKIT 3

NEW

- THE LATEST TOOLKIT BOARD – 8, 18, 28 AND 40-PIN CHIPS
- MAGENTA DESIGNED P.C.B. WITH COMPONENT LAYOUT AND EXTRAS
- L.C.D., BREADBOARD AND PIC CHIP INCLUDED
- ALL TOP QUALITY COMPONENTS AND SOFTWARE SUPPLIED

KIT 880 . . . £34.99 with 16F84 . . . £39.99 with 16F877

PIC TOOLKIT V2

- SUPER UPGRADE FROM V1 ● 18, 28 AND 40-PIN CHIPS
- READ, WRITE, ASSEMBLE & DISASSEMBLE PICS
- SIMPLE POWER SUPPLY OPTIONS 5V-20V
- ALL SWITCHING UNDER SOFTWARE CONTROL
- MAGENTA DESIGNED PCB HAS TERMINAL PINS AND OSCILLATOR CONNECTIONS FOR ALL CHIPS
- INCLUDES SOFTWARE AND PIC CHIP

KIT 878 . . . £22.99 with 16F84 . . . £29.99 with 16F877

EPE PIC Tutorial

At last! A Real, Practical, Hands-On Series

- **Learn Programming from scratch using PIC16F84**
- **Start by lighting l.e.d.s and do 30 tutorials to Sound Generation, Data Display, and a Security System.**
- **PIC TUTOR Board with Switches, l.e.d.s, and on board programmer**

PIC TUTOR BOARD KIT

Includes: PIC16F84 Chip, TOP Quality PCB printed with Component Layout and all components* (*not ZIF Socket or Displays). Included with the Magenta Kit is a disk with Test and Demonstration routines.

KIT 870 .... £27.95, Built & Tested £42.95

Optional: **Power Supply – £3.99, ZIF Socket – £9.99**
LCD Display .... £7.99 LED Display £6.99
Reprints Mar/Apr/May 98 – **£3.00 set 3**

SUPER PIC PROGRAMMER

- READS, PROGRAMS, AND VERIFIES
- WINDOWS™ SOFTWARE
- PIC16C6X, 7X, AND 8X
- USES ANY PC PARALLEL PORT
- USES STANDARD MICROCHIP ● HEX FILES
- OPTIONAL DISASSEMBLER SOFTWARE (EXTRA)
- PCB, LEAD, ALL COMPONENTS, TURNED-PIN SOCKETS FOR 18, 28, AND 40 PIN ICs

- SEND FOR DETAILED INFORMATION – A SUPERB PRODUCT AT AN UNBEATABLE LOW PRICE.

Kit 862 £29.99

Power Supply £3.99

DISASSEMBLER SOFTWARE £11.75

PIC STEPPING MOTOR DRIVER

INCLUDES PCB, PIC16F84 WITH DEMO PROGRAM, SOFTWARE DISC, INSTRUCTIONS AND MOTOR.

Kit 863 £18.99

FULL SOURCE CODE SUPPLIED ALSO USE FOR DRIVING OTHER POWER DEVICES e.g. SOLENOIDS

Another NEW Magenta PIC project. Drives any 4-phase unipolar motor – up to 24V and 1A. Kit includes all components and 48 step motor. Chip is pre-programmed with demo software, then write your own, and re-program the same chip! Circuit accepts inputs from switches etc and drives motor in response. Also runs standard demo sequence from memory.

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TURNING THE WORM

Whilst there has been plenty of popular press coverage about various viruses invading computers via the Internet, until recently we had not experienced any problems. However, over the course of one week at the end of November we received a number of virus-infected emails and two infected disks from regular contributors to our sister publication *Radio Bygones.* In both of these cases neither author was aware of the presence of a virus on their systems.

We know our On-Line Editor Alan Winstanley has frequently had virus attacks – all successfully repelled I'm pleased to say – but we guess because of his high level of internet activity he is more likely to be exposed to this type of problem.

The message is, if you are complacent about virus protection you will eventually be caught out. Don't take chances, the results of these electronic vandals can be expensive and time consuming to fix. Make sure you have some good virus protection software installed and *keep it up to date.* We use Norton AntiVirus in the main office, and Alan uses McAfee AntiVirus plus JBMail – which allows you to delete unwanted mail from your server before it is downloaded – he gave details of this in *Net Work* in the November issue.

Please be warned, these things spread like a rash (sorry, couldn't resist it!).

VIRUS ZAPPER

Speaking of viruses, next month we are publishing a Virus Zapper project – nothing to do with computers, more to do with colds and bodily diseases. This is an easy-to-build unit based on the ideas of Dr Hulda Regehr Clark. Our contributor Andy Flind has developed an inexpensive PIC-based circuit that will provide the necessary output but which also times the various stages of treatment so it is easy to use (see page 75).

Whilst we make no claims for its effectiveness, many people have claimed benefit from such equipment and we will be interested to hear what readers' experiences are in due course. It's a fascinating subject and one that is popular, judging by the number of Internet sites dedicated to it. Our Google search turned up around 16,900 related sites. If you are interested make sure you also read the 'Quackwatch' information. Whatever you believe, we will give you the chance to try the idea for yourself for very little outlay – see next month's issue.

Mike Kenward

AVAILABILITY

Copies of *EPE* are available on subscription anywhere in the world (see below), from all UK newsagents (distributed by COMAG) and from the following electronic component retailers: Omni Electronics and Yebo Electronics (S. Africa). *EPE* can also be purchased from retail magazine outlets around the world. An Internet on-line version can be purchased and downloaded for just $9.99(US – approx £7.70) per year available from **www.epemag.com**

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We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers (see *Shoptalk*). **We advise readers to check that all parts are still available before commencing any project in a back-dated issue.**

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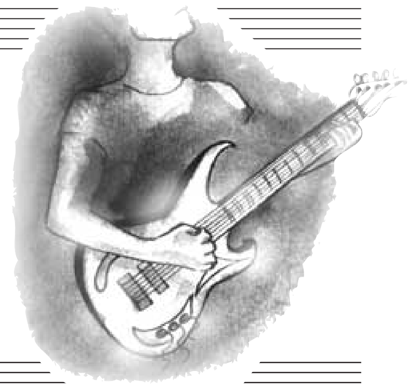
GUITAR PRACTICE AMP

BART TREPAK



A low-cost amplifier that will allow the budding guitarist to improve his playing technique, without annoying the household or neighbours!

COMMERCIAL guitar amplifiers, even those intended for practising, tend to be fairly expensive and have many features such as gain and tone controls which are seldom used, while lacking more useful ones such as an extra input for a microphone or another guitar. The budding musician's money could be better spent on other accessories or even a better guitar, especially as a simple practice amplifier for use with headphones can easily be built around a cheap integrated circuit.

Even a more ambitious version for driving a speaker providing an output of a few watts, which would be quite loud enough to annoy the neighbours or for playing in a small hall, only requires the addition of a cheap power amplifier i.c and a few more components.

EASY-BUILD

Although the cost and number of components required is small, audio power amplifier circuits do not lend themselves to a simple stripboard layout and the problems associated with designing and making a suitable printed circuit board are likely to put off all but the most cost conscious or determined constructors. The simple project to be described here solves this problem and has been designed for easy construction with virtually no off-board wiring apart from the mains transformer, speaker and an optional headphone socket.

Since the printed circuit board is readily available, the circuit can be "knocked up" in a very short time and you should have some change from £25. The finished circuit can be mounted in the same cabinet as the speaker (these can be salvaged from a defunct hi-fi unit) and even if a speaker has to be purchased separately it should not set you back very much.

AMPLIFIER CIRCUIT

The full circuit diagram of the Guitar Practice Amp shown in Fig.1 is very conventional and consists of an inverting preamplifier stage, IC1, feeding a single chip power amplifier, IC2. The op.amp preamplifier IC1 has a variable gain set by preset VR1 to enable this to be set to any required level (up to 100) and should, therefore, be suitable for even the most inefficient guitar pick-ups.

Many small commercial guitar amps often feature tone controls but these are really superfluous as most electric guitars have perfectly adequate tone controls fitted and so these have not been included in this design.

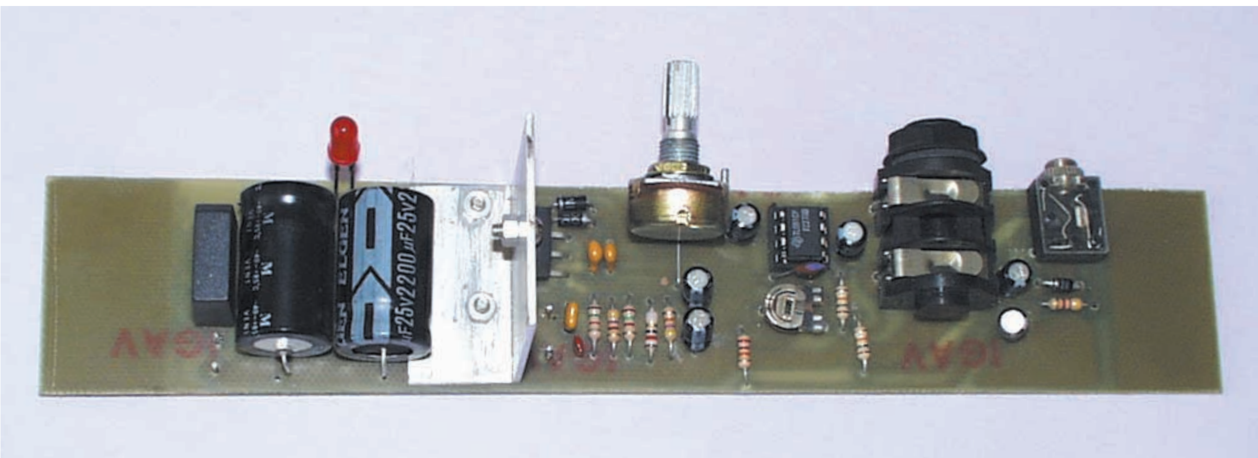
The output of the preamplifier stage (IC1 pin 6) is fed via Volume control VR2 to the power amplifier IC2, which is based around the popular TDA2030. This device can supply up to 24W of audio power depending on the supply voltage and speaker impedance used, provided we are not too bothered about the distortion which in this application can almost be considered to be an advantage.

With the lower supply voltage specified, a more reasonable output power would be about 6W to 10W which should be more than sufficient for our purpose. The power output can be easily increased if required by reducing the speaker impedance or increasing the supply voltage, and no changes in the component values are required.

It should, however, be remembered that the maximum supply voltage for both i.c.s is 36V. The TDA2030 is a very well protected device featuring both short circuit and over dissipation protection although from a reliability point of view it is certainly not advisable to run the device in either of these conditions.

Music generally tends to have many peaks while the average power dissipated remains low so that in practice, despite the use of the relatively small heatsink specified, the temperature of the device will remain well within its safe limit even with prolonged loud playing. Also, as the circuit is permanently connected to the speaker (except when in headphone mode) the possibility of a short circuited output is much reduced.

An (optional) output socket SK3 is also wired in circuit to enable headphones to be connected in place of the speaker LS1.



This is arranged so that inserting the headphone jack plug automatically disconnects the speaker. It also switches in a resistor, R11, in series with the headphones to prevent overloading, see Fig.1 and Fig.3.

Both the resistor and the headphone socket are mounted off the board and it will be noticed that the headphones which normally have an impedance of 32 ohms (each) are connected in series.

POWER SUPPLY

The circuit is completed by a conventional power supply consisting of mains transformer T1, bridge rectifier REC1 and smoothing capacitors C12, C13. It provides a d.c. supply of +12V and –12V and although a single rail supply could have been used, the advantage here is that the usual large speaker coupling capacitor is not required.

This may not seem to be such an advantage when it is realised that two capacitors are now required in the power supply, but it does mean that the annoying “switch-on thump” normally associated with these amplifiers (due to the speaker coupling capacitor charging up) is eliminated. The relatively low impedances in the circuit mean that hum and noise pick-up is low so that an l.e.d. D4 Power On indicator has been included to remind the user to switch off!

ELECTRET MICROPHONE

Most of today’s top hits are songs and playing chords on their own does not sound very good, it is far better if the “artist” can sing along while playing. With an electric guitar a microphone is required to avoid having to shout rather than sing.

Nowadays headphones which include a microphone are available from any computer store for around £5 and these are eminently suitable for this application. Many practice amplifiers however, have only one input and cannot easily accommodate a microphone but this deficiency has been rectified in this design by adding a simple mixer.

The microphones incorporated in these cheap headsets are usually “electret” types. The microphone element constitutes in effect a very high impedance source and a buffer amplifier (consisting of a field effect transistor or f.e.t.) is normally incorporated within the microphone capsule as shown inset in Fig.1.

This requires a small supply voltage (between 1·5V and 5V) and a load resistor to operate and so the components associated with the microphone input have been added to supply this. A nominal 5V supply is derived from the main supply rail via resistor R1 and Zener diode D1 while R2 forms the load resistor for the f.e.t. inside the microphone capsule.

Note that a stereo jack socket (SK2) is used for the microphone with the second terminal supplying the +5V while the signal is picked up from the centre pin (tip) and the outer earth (0V) connection in the normal way. (The centre pin and the second terminal are connected inside the microphone). This allows a different microphone such as a dynamic type for example, which does not need a supply voltage or resistor, to be connected and in this case the 5V supply will simply be

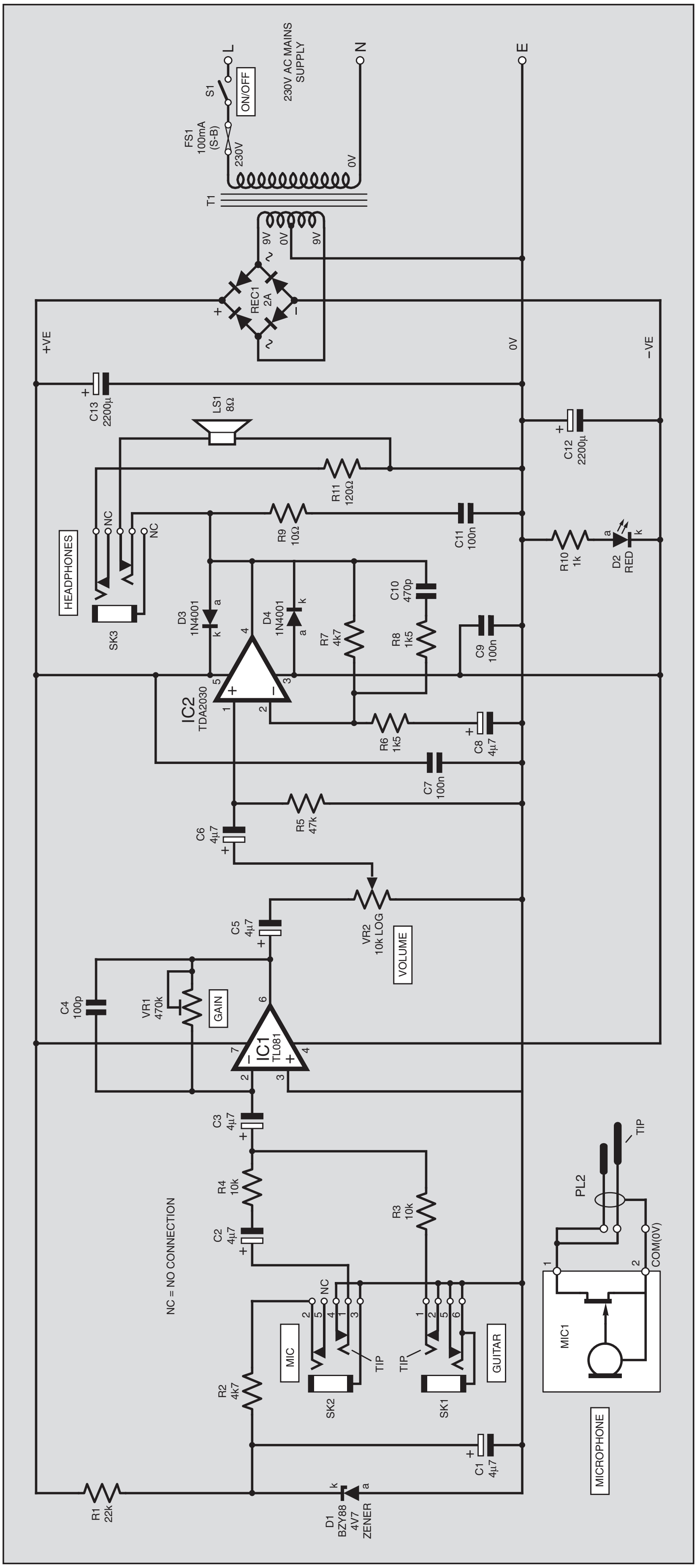


Fig.1. Complete circuit diagram for the Guitar Practice Amp.

shorted to earth by the microphone's mono jack plug causing no damage to either the microphone or amplifier.

ALL MIXED UP

The signal from the microphone is fed to the input of the amplifier via another input resistor R4, the value of which together with the feedback control (resistor) VR1 defines the gain of this channel. A 10 kilohms resistor was found suitable in the prototype but this may be changed if required, a higher value resulting in a lower gain and vice-versa.

This stage (IC1) of the circuit forms an ideal signal mixer since the inverting input (pin 2) of the amplifier is a "virtual earth" so called because the op.amp IC1 maintains the voltage at its inverting input at zero volts. It does this by changing its output voltage when a change in the input voltage tries to upset this and as the feedback preset VR1 has a higher value than the input resistor R4, the output voltage change is higher resulting in a voltage gain.

Another way to visualise this is to realise that an op.amp always tries to maintain both of its inputs at the same potential which in this case is 0V. This means that the microphone channel will not be affected by any changes in the volume or tone settings of the guitar which is also connected to this point via its own resistor R1.

VIRTUAL EARTH

A general circuit of a "virtual earth" mixer is shown in Fig.2. and there is nothing to stop you connecting another guitar or other signal source such as a tape or CD player in the same way simply by adding another input socket, connected to IC1's inverting input by its own resistor as shown. The values of the resistors would, of course, have to be chosen carefully to avoid over driving the amplifier. The output of a CD player for example would be much larger than that of a guitar so that its resistor would need to have a higher value.

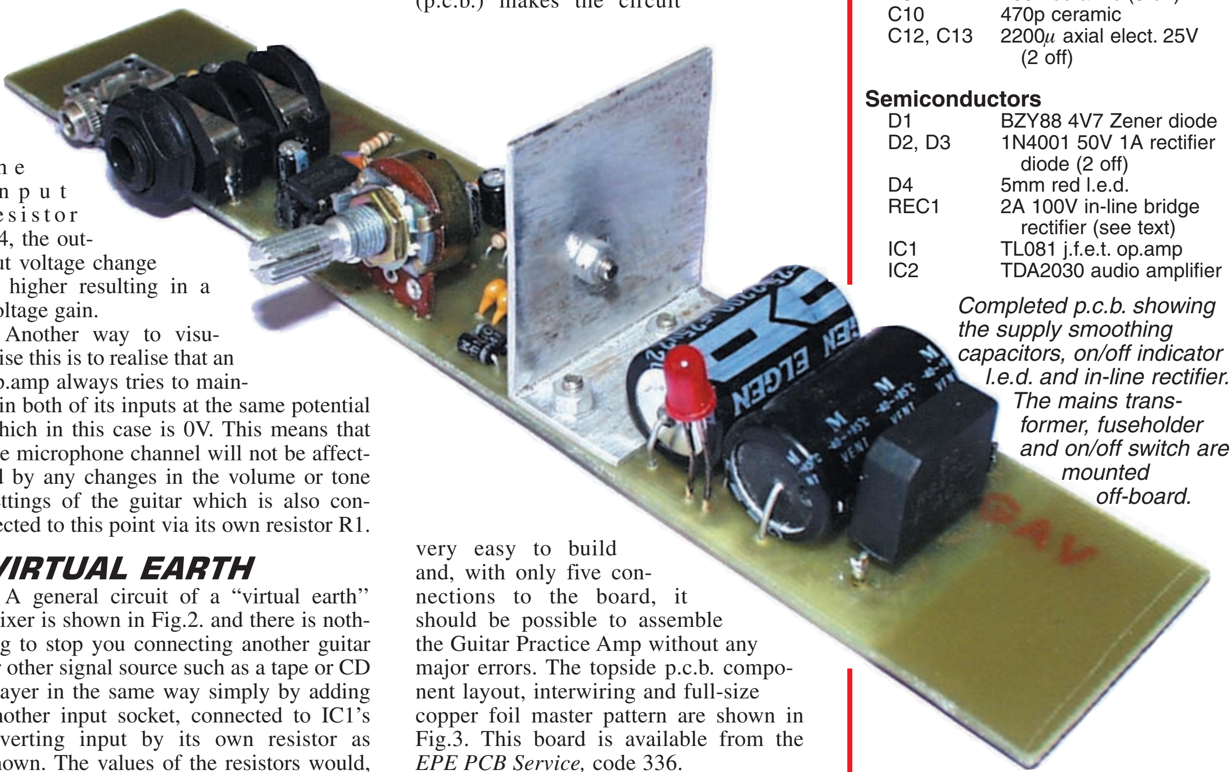
Alternatively, each channel could have a separate volume control fitted as shown. It would also be a good idea to fit d.c. blocking capacitors to prevent any d.c. on the output of the CD player or other device upsetting the bias conditions of the op.amp.

No separate provision for controlling the volume of the microphone channel has been made in this version as the relative volume of the guitar can be controlled at the instrument itself while VR2 controls the overall volume.

CONSTRUCTION

This is a mains operated circuit and its construction should not be attempted by those who are not suitably experienced or supervised.

The use of a printed circuit board (p.c.b.) makes the circuit very easy to build and, with only five connections to the board, it should be possible to assemble the Guitar Practice Amp without any major errors. The topside p.c.b. component layout, interwiring and full-size copper foil master pattern are shown in Fig.3. This board is available from the *EPE PCB Service,* code 336.



Completed p.c.b. showing the supply smoothing capacitors, on/off indicator l.e.d. and in-line rectifier. The mains transformer, fuseholder and on/off switch are mounted off-board.

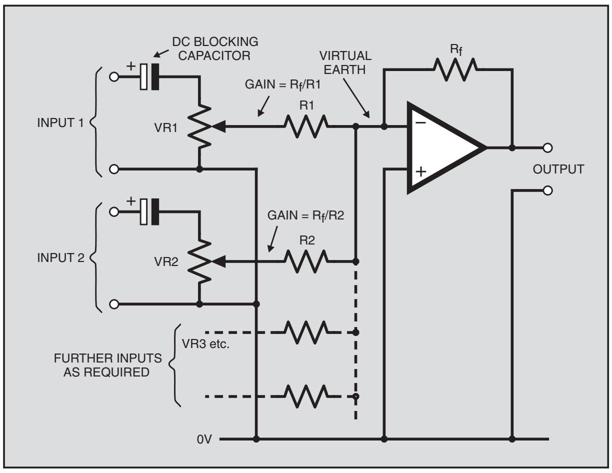


Fig.2. Adding extra inputs to the "virtual earth" mixer circuit.

COMPONENTS

See SHOP TALK page

Resistors

R1	22k
R2, R7	4k7 (2 off)
R3, R4	10k (2 off)
R5	47k
R6, R8	1k5 (2 off)
R9	10Ω
R10	1k
R11	120Ω

All 0·25W 5% carbon film or better

Potentiometers

VR1	470k carbon preset, lin.
VR2	10k rotary carbon, log.

Capacitors

C1 to C3, C5, C6, C8	4µ7 radial elect. 50V (6 off)
C4	100p ceramic
C7, C9, C11	100n ceramic (3 off)
C10	470p ceramic
C12, C13	2200µ axial elect. 25V (2 off)

Semiconductors

D1	BZY88 4V7 Zener diode
D2, D3	1N4001 50V 1A rectifier diode (2 off)
D4	5mm red l.e.d.
REC1	2A 100V in-line bridge rectifier (see text)
IC1	TL081 j.f.e.t. op.amp
IC2	TDA2030 audio amplifier

Miscellaneous

SK1	6·35mm (¼in.) moulded mono jack socket, with 2 switched break contacts
SK2, SK3	3·5mm stereo jack socket, with 2 switched break contacts (2 off)
MIC1	sub-min. omni-directional electret microphone insert
S1	s.p.s.t. mains rated on/off toggle switch
FS1	100mA 20mm slow-blow fuse
T1	18VA 230V a.c. mains transformer, 9V-0V-9V secondaries (see text)

Printed circuit board available from the *EPE PCB Service*, code 336; 8-pin d.i.l. socket; panel mounted fuseholder; aluminium heatsink, size 38mm x 58mm approx.; control knob; multistrand connecting wire; mains cable; 8Ω speaker, type to choice; solder pins; solder etc.

Approx. Cost Guidance Only **£24** ***excluding speaker & case***

Assembly of the board should begin by inserting the terminal pins which will be used to connect the speaker and transformer to the p.c.b. These usually require a certain amount of force to insert into the board which could damage adjacent components if this were done at a later stage.

Once the solder pins have been fitted, the board may be completed by mounting resistors, diodes, capacitors etc. in ascending order of height. Care should, of course, be taken to ensure that diodes and electrolytic capacitors are inserted the correct way around. Note also that a wire link (made from a discarded component lead) and a resistor (R10) are mounted under C12 and C13 so that these components must obviously be fitted before the electrolytic capacitors are mounted on the board. A second wire link is also required between C6 and VR2.

Although IC1 is not a CMOS device, and thus not particularly sensitive to static, it is worth fitting an i.c. socket to prevent any possibility of overheating it during the soldering operation this will also facilitate its easy removal should this be required.

POWER AMP

The audio power amplifier IC2 is more difficult to fit and before this is done it is best to prepare the small heatsink according to Fig.4. In the prototype this was made from a piece of L-shaped aluminium extrusion normally sold in DIY shops but should this not be easily obtainable a suitable piece of sheet aluminium bent to shape and drilled as shown will do just as well.

IC2 should be mounted on the board but its leads should not be soldered for the moment. Once this has been done, the heatsink can also be mounted on the board and secured to it using two nuts and bolts. When it is secure, IC2 should be bolted to it, via its metal tab, and it is here that the

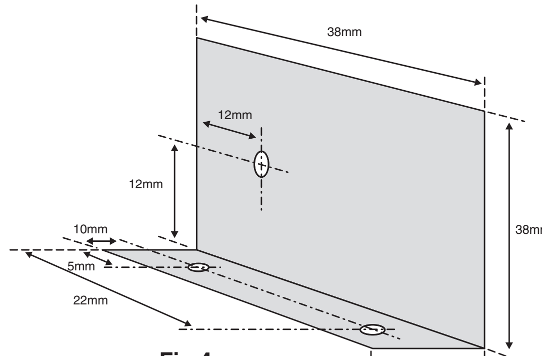


Fig.4

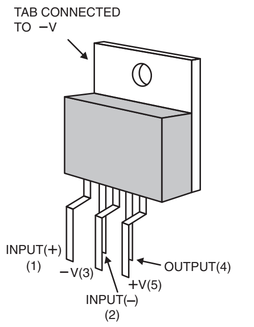
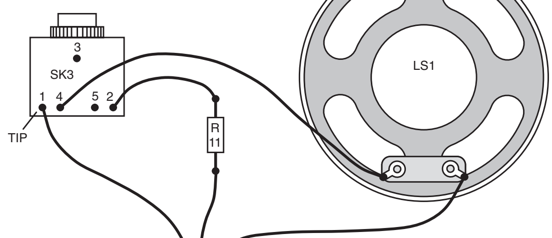


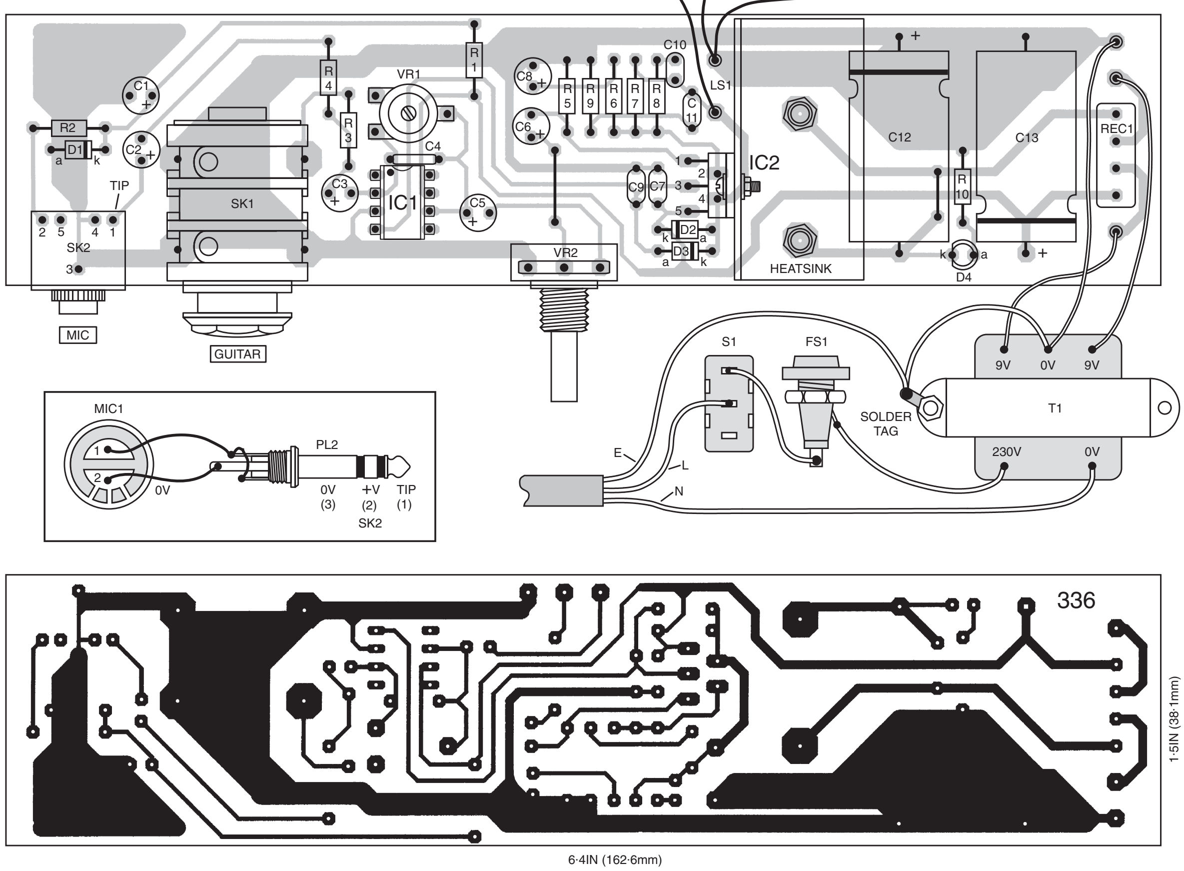
Fig.5

Fig.4 (top right). Heatsink dimensions and bending details.

Fig.5 (top, far right). Pinout details for IC2, the TDA2030 audio amp.

Fig.3. Printed circuit board component layout, wiring and full-size copper foil master. The wiring to the microphone insert jack plug PL2 is shown inset below.





advantage of delaying the soldering of this device will be seen as this will allow a certain amount of tolerance in the final positioning of the device relative to the heatsink.

Once IC2 is secured to the heatsink, its leads can be soldered and trimmed in the normal way. Note that it may also be necessary to bend the leads slightly to enable it to fit the holes in the board, see Fig.5.

Most devices are supplied with the leads already pre-formed although it should be noted that the TDA2030 is available with the leads formed for both vertical and horizontal mounting. Both types are identical but the vertical device is to be preferred as quite a lot of lead bending would be required to fit the horizontal device.

A smear of silicone grease between the heatsink and IC2's tab will help to conduct heat away from the i.c. but this was not found necessary on the prototype. What is important however is to ensure that there is a good *electrical* path between the tab and the negative supply p.c.b. copper track. For this reason no mica washers or any other insulation should be fitted between the tab of IC2 and the heatsink.

The heatsink is used as a negative supply connection to the chip and it ***must not*** be earthed or connected to any other part of the circuit. The pinout details of the TDA2030 are shown in Fig.5 for reference.

The only other component worthy of individual mention is the bridge rectifier where a 2A device is specified. A 1A device could also be used but this was not available in the author's spares box. These are available in many variants and shapes and although any of these devices will do, the board has been designed for an in-line package and so this type should be purchased if possible to avoid a lot of lead bending.

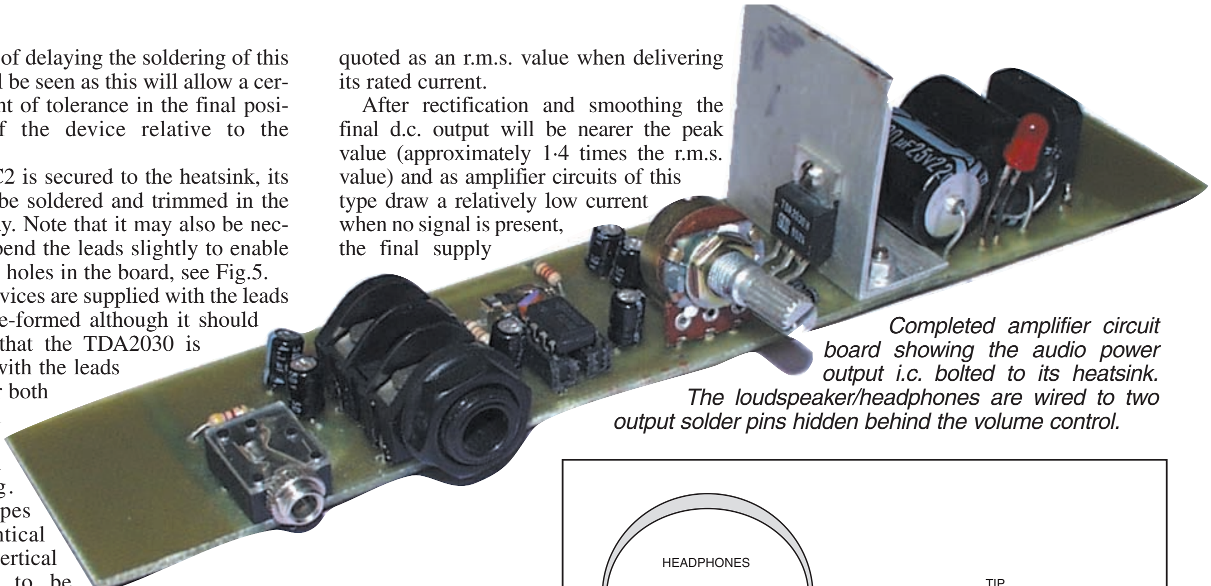
PRELIMINARY CHECKS

After careful checking of the board to ensure that there are no solder splashes between the tracks and that all the joints are sound, the speaker and mains transformer connections should be made to the board. The transformer used in the prototype had wire leads but if another type is used, then wires may need to be fitted.

Printed circuit board mounting types should be avoided as these usually lack mounting brackets and in this case the transformer will need to be mounted on a chassis or in the wooden cabinet containing the speaker. The final arrangement will depend to a large extent on circumstances and is therefore left to the individual to solve.

Care should be taken to ensure that a transformer with a centre tapped secondary (or with two secondary windings which can be connected in series) is used and although a voltage of 9V-0V-9V is specified, a slightly higher output could also be used. It should be remembered that the output of a transformer is always quoted as an r.m.s. value when delivering its rated current.

After rectification and smoothing the final d.c. output will be nearer the peak value (approximately 1·4 times the r.m.s. value) and as amplifier circuits of this type draw a relatively low current when no signal is present, the final supply voltage could be even higher depending on the transformer used. The supply voltage should, therefore, be measured to ensure that it does not exceed the ratings of the i.c.s (i.e. plus and minus 18V). The centre tap of the secondary must be connected to the 0V rail (corner terminal of the p.c.b.) while the other two leads may be connected to the other two terminals either way around.



Completed amplifier circuit board showing the audio power output i.c. bolted to its heatsink. The loudspeaker/headphones are wired to two output solder pins hidden behind the volume control.

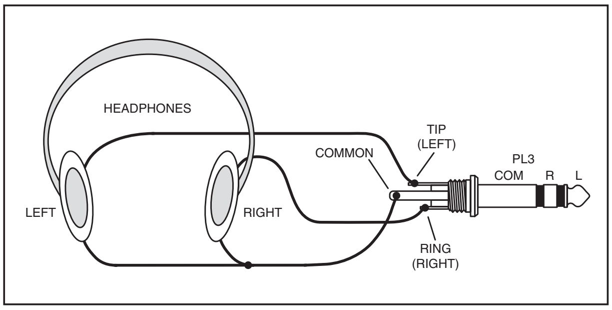


Fig.6 (right). Headphone jack plug PL3 wiring. The headphone jack socket (SK3) contacts break when the plug is inserted, disconnecting the loudspeaker LS1.

FINAL ASSEMBLY

The mains wiring should be carried out carefully and all joints well insulated to ensure that they cannot be touched inadvertently when the unit is in operation. A mains On/Off switch and a fuse should also be fitted in the live mains lead and the mains cable securely clamped to the box or cabinet using a suitable strain relief mounting bush.

The speaker will also need to be connected to the output terminals using suitable lengths of wire. If a socket for headphones is to be included, this should be arranged to disconnect the speaker when the jack plug is inserted so that a switched socket will be required (see Fig.1 and Fig.6).

The finished p.c.b. is quite light and so no special mounting hardware is required. It should be adequately supported by the potentiometer spindle and the input jack sockets but the final details of this are left to the constructor and will depend to a large extent on the cabinet in which the p.c.b. and speaker are mounted.

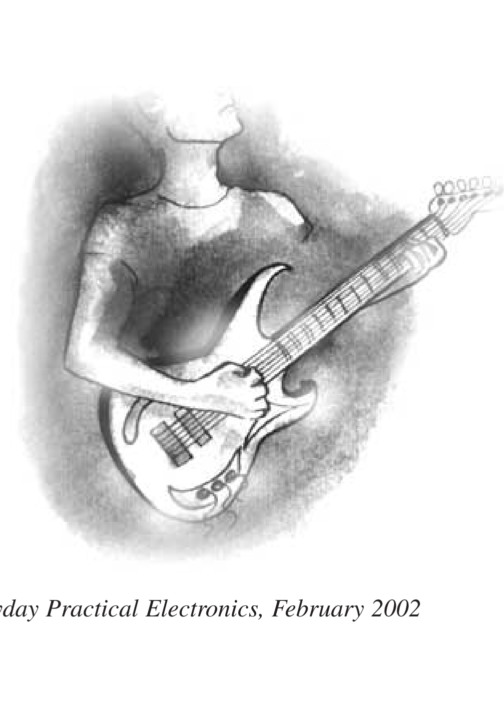
FINAL TESTING

When fully assembled, check the wiring again, especially around the headphone socket and transformer primary and if all is well, connect the unit to the mains and switch on. The voltage across each of the two smoothing capacitors can be measured and this should be about 12V d.c but no higher than 17V.

A slight hum or hiss may be audible from the speaker if the Volume control VR2 is turned up fully. Turn down the volume and connect a guitar which should now be heard.

The only adjustment to be made is to set the gain of the preamplifier stage (IC1) and this should be done with the volume turned up to maximum on VR2 and the guitar. Starting with preset VR1 turned fully clockwise the gain should be increased until distortion is heard when a string is played. An oscilloscope is useful here but not necessary as it is the final sound that is important and not the apparent purity of the output waveform.

If required, the headphones can be plugged in and, provided the wiring has been done correctly, this should switch off the speaker. With this "adjustment" complete, the stage act can be perfected without interference from the rest of the household. Take it away Eric . . . □



New Technology Update

Will improvements in electrolytic capacitor technology and manufacture prove to be the demise of the tantalum? asks Ian Poole.

LIKE other areas in the electronics scene, capacitor technology is moving forward apace. Capacitors are being made smaller as a result of the ever-increasing size restraints that are being placed on equipment, and in addition to this the performance is being improved.

One of the major types of capacitor is the electrolytic. It is capable of providing a very high capacitance density and as a result it is widely used where high levels of capacitance are required.

Unfortunately, all capacitors have some unwanted parasitic elements and electrolytic capacitors are no exception. One of the major unwanted effects is the equivalent series resistance or ESR. This exists because the conductive plates are not perfect conductors and there is a loss introduced by the dielectric.

Electrolytic Capacitors

Like any other type of capacitor an electrolytic has two plates. As the dielectric consists of a very thin layer of oxide on the anode plate in the capacitor it is hazardous to bring both the anode and cathode plates directly in contact with one another. To overcome this problem an electrolyte is placed between the cathode and the anode, see Fig.1. In this way a conductive path is provided whilst reducing the possibility of physical short circuits.

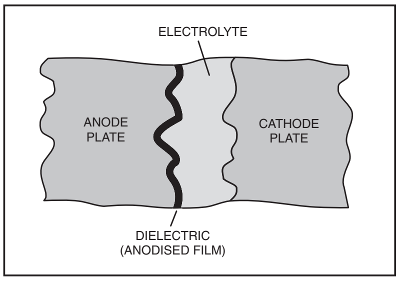


Fig.1 Operational aspects of an electrolytic capacitor.

The traditional method of manufacturing electrolytic capacitors is to roll up a sandwich of the required layers and to place it into a metal can (casing). The layers consist of the anode formed from aluminium foil with its oxide layer, an absorbent spacer soaked with electrolyte, then the cathode plate and finally another spacer soaked with electrolyte, see Fig.2. The metal can is connected to the cathode and the anode connection is brought out through a seal at one end of the component.

The electrolyte soaked spacer is required to prevent abrasion, however slight, between the anode and cathode films breaking through the very thin oxide layer on the anode and causing a short circuit. As a result this construction technique means that there is a relatively large gap between the foils in the structure. A much greater level of capacitance could be achieved if the two capacitor layers could be brought closer together.

ESR

The ESR in a capacitor reduces the performance of the component by effectively placing a resistor in series with the capacitor. It can also give rise to heat dissipation within the capacitor if it is used in applications such as power supply smoothing where the levels of current flowing in the component are relatively high. By improving the ESR of the capacitor its electrical performance can be improved in the circuit, and it can be used for higher current capability applications.

Most of the ESR is caused by the resistance of the cathode itself and arises chiefly from the electrolyte, although the foil does contribute as well. As a result any improvements in the materials that can be used for the cathode could give significant improvements in performance.

Polymer cathodes

In some new developments, conductive polymers can now be used in capacitors to overcome some of these problems. Their use in capacitor technology was originally proposed by some Japanese manufacturers where they were used as substitutes for the cathode connection.

The polymer has the advantage that it can now be chemically deposited onto the anode oxide in a fashion that will not cause abrasion that will break down the oxide layer. This is accomplished by generating a new stacked foil structure, see Fig.3.

The foils are anodised, and then bonded to give a single structure. The bond connects all the foils together but leaves areas that are not insulated. To ensure that none of the anode areas are exposed an insulative coating is used to fill in this area.

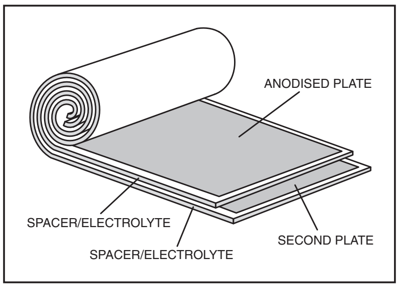


Fig.2. Construction of a traditional aluminium electrolytic capacitor.

Next, the structure is dipped in a monomer solution. This flows between the foils and quickly polymerises to give the conductive coating. Once the solution has polymerised and dried it is dipped into a silver epoxy solution so that the cathode connection is extended over much of the polymer film. This silver epoxy is then bonded to the cathode lead frame whilst the anode lead frame is welded to the bonded area of the anode foils or plates.

The component is completed by moulding the device in a plastic epoxy. It then looks very much the same as a tantalum capacitor.

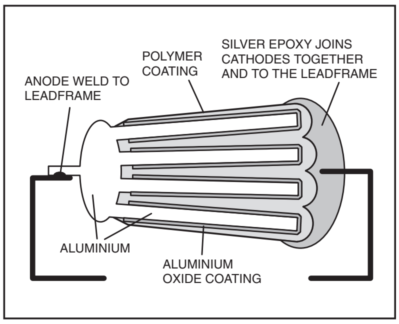


Fig.3. Construction of the new electrolytic capacitors.

Performance

Using the new techniques with the polymer film the new electrolytics show a vast improvement in the level of ESR. This is attributed to both the material change as well as the construction technique.

A typical 47µF 6V component shows the level of ESR falling below 0·01 milliohms with a useable frequency response extending above 10MHz. Using standard electrolytic capacitors the frequency response was limited to operation below frequencies of 1MHz, and usually much less.

Cost is another very important factor. The performance of the new device is such that it will enable cost reductions to be made on many boards, purely because its improved performance means that fewer capacitors will be needed in many instances.

In view of these factors it is likely that the new design of electrolytic capacitors will be appearing in the catalogues before long. Also as the same techniques can be applied to tantalum capacitors, similar performance improvements will be seen in this field as well. However, as tantalum is very expensive and supplies are not guaranteed, component manufacturers will be able to offer improved levels of performance using electrolytic capacitors, thereby reducing the reliance on tantalum.

News . . .

A roundup of the latest Everyday News from the world of electronics

CYBER-TERRORISM

Operating systems and users alike are woefully remiss at maintaining adequate virus protection, reports Barry Fox.

SYMANTEC, the software company behind the Norton Utilities and AntiVirus program, warns that cyber-terrorism is the warfare of the future. The Carnegie Mellon University in Pittsburg has recorded 34,000 computer attacks this year alone, 90 per cent of them from malicious code viruses.

The best way to categorise an attack is to describe its effect, says Symantec and specialist security company, mi2g.

Piracy can result in credit card details being sucked from supposedly secure Web sites, and sold in batches of 1000 from Romania. Surrogacy is where hackers steal someone's identity, for instance hijacking the BBC Web site for Kashmiri propaganda. Distributed Denial of Service means that Web sites like Ebay, Yahoo and CNN are flooded with spurious messages sent by hijacked computers round the world. Hazards can be an attack on a nuclear power station safety system, a power supply for an airport or the threat of publishing personal details of petroleum workers using false names in Nigeria.

Insider Raiding

Symantec estimates that 70 per cent of cyber attacks are made by insiders, for instance disgruntled employees; and hitech companies regularly lay off skilled workers. The Arabic version of Windows was developed in Cairo, so there is local knowledge of the code base and its weaknesses.

The new version of Windows, XP, does little to curb the spread of viruses which infect a PC when Outlook runs executable code in an arriving email. The default for XP is not to run them. "But if you click Yes when it asks whether you want to run embedded code it never asks again and goes on opening them", warns Robert Clyde, Symantec's Chief Technology Officer. "You get your streaming stock market quotes but you can also get viruses".

"Until recently the financial institutions have not shared information on attacks" says Clyde. "Each bank is its own silo".

The Wireless Ethernet standard 802.11 has already been hacked, so people can sit outside an office and eavesdrop on an office's internal wireless communications.

Viruses R Us

Anyone can be a hacker. There are now 30,000 Web sites at which would-be hackers can learn how to hack. Web site servers and any PC that remains permanently online, for instance with a broadband ADSL connection, can now expect to be scanned at least ten times a day by hackers with automatic probe software, looking for security loopholes.

Robert Clyde says that when Symantec surveyed Web sites, they found only 40 per cent had Level 7 (top level) fire wall protection to keep out hackers. Only half the world's computers are protected against viruses. Of 200,000 PC users with anti-virus software, 48 per cent had not updated it to catch new viruses and one-third already had viruses in their PCs, but did not know it.

TETRA NOT PULSED

WE have previously reported on the suggestion that TETRA (Terrestrial Trunked Radio) signals might be hazardous to human health due to them being pulsed.

The National Radiological Protection Board (NRPB) have recently stated that measurements show that TETRA base station signals are continuous and not pulsed over time intervals that could cause power modulations at frequencies between 1Hz and 200Hz.

For more information browse **www.nrpb.org.uk**.

PHYSICS CONGRESS 2002

THE Brighton Conference Centre will host the *2002 Physics Congress* from 7 to 11 April this year. We are informed that in addition to lectures for delegates, there will be public lectures and debates, plus hands-on physics exhibits and physics fun for all the family. There will also be a special programme of events for school children, including an astrodome and a cybercafe.

Amongst the family-orientated features, from Sunday 7th to Wednesday 10th there will be hands-on exhibits with puzzles, challenges and scientific marvels to enthuse and amuse, as *Techniquest* comes to Brighton.

There is a *Madlab* electronics workshop for children and adults who wish to learn how to use a soldering iron, and actually make and take home a working electronic circuit. You can also step into the world's largest mobile planetarium and watch a high-tech interactive show with computer graphics and NASA video clips. Furthermore, *Science in a Suitcase* is presented by Bob Ward and Julia Sherratt who will display "super science in simple scenarios".

It all sounds too good to miss – for more information browse **http://congress.iop.org** or contact the Institute of Physics, 76 Portland Place, London W1B 1NT. Tel: 020 7470 48000. Fax: 020 7470 4848, Email: physics@iop.org. Web: www.iop.org.

MICROCHIP'S NEW OP.AMPS

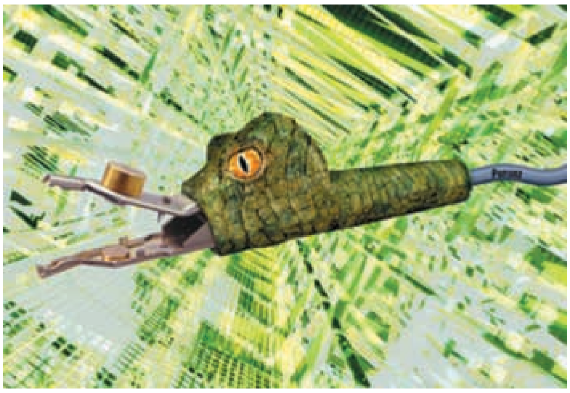
MICROCHIP, the manufacturers of PIC microcontrollers, have announced new families of low voltage, low current op.amps having unity gain stability. The MCP602x and MCP604x families also have rail-to-rail input and output, and are ideal for battery-powered applications.

The MCP602x devices support a voltage supply range from 5·5V down to 2·5V. The MCP604x voltage range is from +5·5V down to 1·4V and requires only a miserly 600nA of quiescent current (IQ), which means that these devices can be used without cost stabilising circuitry. Those of you following the current *Teach-In 2002* series will now appreciate how important op.amp stability is when dealing with d.c. outputs from sensors.

To support the MCP602x and MCP604x families, Microchip offer the FilterLab Active Filter Design Tool. It is available free from Microchip's web site and provides schematic filter circuit diagrams.

For more information browse **www.microchip.com**.

ALLIGATOR TESTING



CURIOUS how animals keep getting into the workshop – bulldog clips, crocodile clips, CATalogues, and now alligator clips with a difference! They have been introduced by Pomona Electronics and are wire-piercing clip test leads, basically for automotive testing but no doubt equally suitable for use with any insulated low-voltage leads ranging from 14 to 26 s.w.g.

Designed for use with multimeters that accept safety-shrouded banana plugs, these new test leads eliminate the need for insulation stripping and significantly reduce test time. They also attach to blade-shaped or threaded terminals, screw heads and bare wires.

Available in four model configurations to meet a variety of test requirements, the Alligator Clip Test Lead series features a variety of needle styles, including a "row of points" configuration, which minimises wire penetration and reduces the likelihood of wire breakage.

For more information of these and other test accessories, contact Pomona Electronics Europe, PO Box 1186, 5602 Eindhoven, Nederlands. Tel: +31 (0)40 2678 150. Fax: +31 (0)40 2678 151. Web: www.pomonaelectronics.com.

SMART CARDS WITH 1MB

SHARP comment that Smart Cards are becoming increasingly powerful and that personal ID, credit, cash and phone cards and driving licenses are shrinking to Smart Card formats.

While some of these cards are still made from cardboard, more and more are becoming intelligent and already have chips to increase security and store critical data. Simple models operate by means of contacts, while the advanced ones use non-contact radio waves and induction. Traditional technologies typically offer 64KB of memory, processor speeds of 1 to 2MHz and data transfer rates of 9·6 (via contacts) to 106 Kbits/sec (non-contact).

Sharp say they have broken away from traditional models and now offer a powerful Smart Card system featuring a processor operating at speeds up to 24MHz and having a 1MB flash memory chip. Possible data transfer speeds are likely to exceed four to eight times that of old cards to take into account the increasing volumes of data to be exchanged during transactions.

For more information browse **www.sharpsme.com**.

LABCENTER AND IAR

LABCENTER Electronics and IAR Systems have announced collaboration on simulations for complete board designs. In a first step, IAR's UBROF debugging format will be supported by Labcenter's Proteus VSM tool to allow source level debugging of board designs featuring a PIC, AVR or HC11 microcontroller and peripherals.

Proteus simulates complete embedded systems, including the CPU and peripherals. Code compiled with any supported IAR compiler can be debugged in source code mode within the Proteus environment.

"By entering this partnership, we breakdown the barriers between software and hardware development", say IAR. Labcenter comment that "Proteus VSM is unique in combining interactive SPICE circuit simulation, animated components and detailed CPU models. Add to this a link-up with industrial strength compilers such as IAR's and you have something quite remarkable".

For more information contact Labcenter Electronics, 53-55 Main Street, Grassington, N.Yorks BD23 5AA. Tel: 01756 753440. Fax: 01756 752857. Web: www.labcenter.co.uk.

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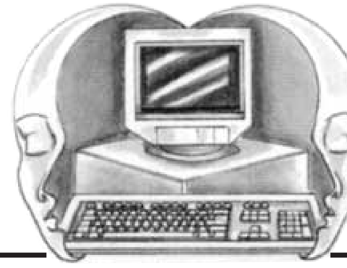
INTERFACE



Robert Penfold

PRODUCING A DIY MIDI ADAPTOR FOR YOUR PC

THE SUBJECT of suitable alternatives for the defunct TLC548IP A/D chip was covered in the previous *Interface* article. Further experience with the TLC549IP and TLC548CP seems to indicate that either chip will work fine in the various *EPE* circuits that were designed for the TLC548IP.

The TLC549IP is generally cheaper than the TLC548CP, and although its parameters are in some cases inferior, it is adequate for all the *EPE* circuits. If you are "doing your own thing" and need the highest possible conversion rate, the TLC548CP is the better choice.

Fun and Games

The subject of the PC's MIDI interface is one that crops up from time to time in correspondence from readers, and it is an aspect of the PC that is less straightforward than one might hope. As most readers are probably aware, virtually every PC soundcard has a built-in game port that also acts as a MIDI interface. An increasing percentage of PCs have the sound generator integrated with the motherboard, but the game/MIDI port is still included.

This is fine until you actually try connecting MIDI keyboards, drum machines, etc. to a PC. The obvious problem is that the standard MIDI connector is a 5-way (180-degree) DIN socket, but XLR connectors can be used provided the equipment manufacturer makes suitable DIN to XLR adapters available.

The 15-way D-connector used for the PC's combined game and MIDI port is clearly incompatible with standard MIDI leads. Readers sometimes request details of the ins and outs of this port so that they can make up PC MIDI leads.

Unfortunately, the lack of compatibility extends beyond the use of an inappropriate connector. The ports on modern soundcards are based on the early SoundBlaster cards, which omitted a few components from the MIDI port.

Some up-market soundcards do actually have the correct connectors and complete interfaces, but if your soundcard has a 15-way D-connector, it is almost certainly a few components short of an interface. Consequently, wiring the port to a couple 5-way DIN sockets is unlikely to get it working properly with a MIDI system.

DIY Adapter

Ready-made PC MIDI adapters are produced but can be difficult to obtain. There is more chance of finding one in a store that specialises in electronic music gear than at a computer shop.

It is not difficult to make your own adapter, and few parts are required. The functions of the game port's terminals, when it is used as a MIDI interface, are shown in Fig.1. The MIDI input terminal replaces what is normally a +5V supply pin on the game port. Similarly, the MIDI output terminal replaces what would otherwise be a ground (0V) pin.

Connecting the output to a synthesiser, etc. is relatively easy, since MIDI does not require any opto-isolation on outputs. A simple arrangement for adding a MIDI output facility is shown in Fig.2. Only one resistor is needed in addition to the connectors and screened lead. A male 15-way D-connector is needed to make the connection to the PC's MIDI port.

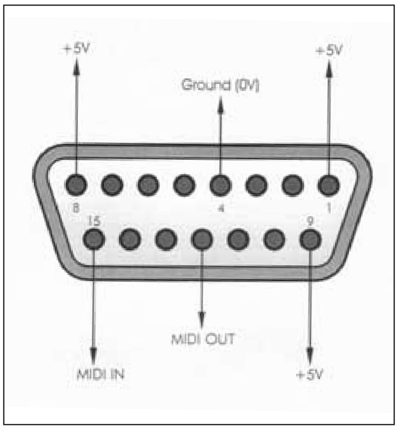


Fig.1. The pin functions of the game port when it is used as a MIDI interface.

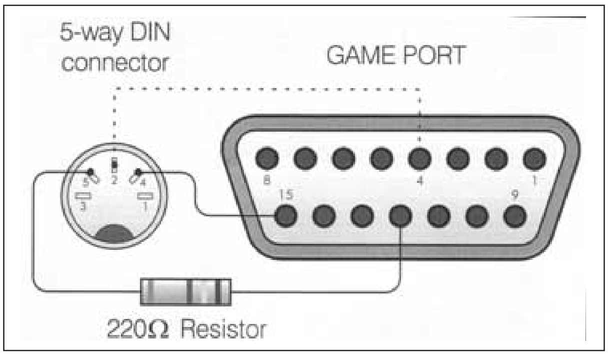


Fig.2. Adding a MIDI output facility.

Probably the best type of cable for MIDI leads is a twin screened audio cable, and it is worthwhile getting a good quality type. The screen connects to a ground terminal at MIDI outputs, but it is not connected at MIDI inputs.

If the unit is built as an adapter that enables ordinary MIDI leads to be used with the PC, the DIN connector must be a socket. The connection represented by the broken line must then be included, so that the screen of the MIDI cable will be earthed at the PC. If it is built as a lead that permits the PC to be connected direct to a MIDI instrument, the DIN connector must be a plug.

The screen of the cable connects to pin 4 of the game port. There is no need to connect the screen to pin 2 of the DIN plug because this pin is not connected at MIDI inputs. Connecting the screen to earth at inputs would bypass the opto-isolation.

MIDI Input

The opto-isolation is used to prevent digital noise from a device such as a computer finding its way into the audio circuits of a MIDI instrument. It has other benefits, such as helping to avoid the audio "hum" that can result from earth loops.

Another important advantage is that it eliminates the risk of high voltages zapping devices when they are connected together. This can occur when using equipment that is double insulated rather than earthed, due to the high

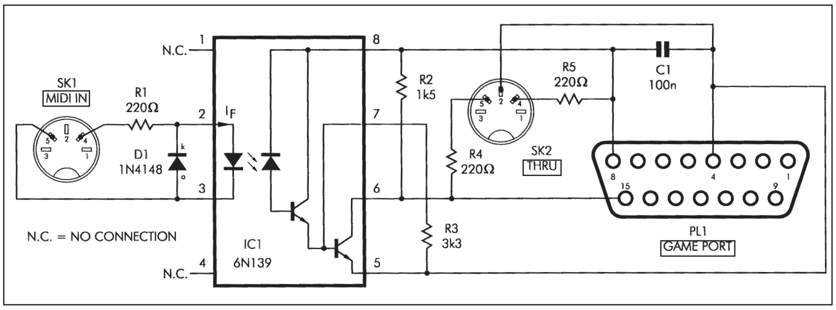


Fig.3. Circuit diagram for the MIDI Input and Thru interfaces. IC1 is a sensitive, high speed split-Darlington opto-isolator.

voltages that can exist between the chassis of the various items in the system. Although the available current is strictly limited, the high voltages can destroy sensitive semiconductors.

A SoundBlaster style MIDI input is a straightforward logic input, and no opto-isolator circuit is included. The circuit diagam of Fig.3 puts in the missing components.

Opto-isolators are very slow by normal electronic standards, and most are not suitable for use with MIDI signals. MIDI is a serial system that operates at 31,250 baud, which is well beyond the capabilities of "bog standard" opto-isolators.

The drive current is only 5mA, so a fairly efficient opto-isolator is required. The normal choice of optocoupler is the 6N139 or a similar device. This is a sensitive, high speed "split-Darlington" opto-isolator in an 8-pin dual-in-line (d.i.l.) package. Speeds of up to 300 kbits/s are claimed for this device.

On the output side, this has a photodiode driving a common emitter output stage via a simple buffer amplifier. Note that this arrangement is not the same as a Darlington pair, and that opto-isolators that use Darlington outputs stages are much to slow for this application.

Resistor R1, together with resistors at the MIDI output, limit the internal opto-isolator l.e.d. current to 5mA. Diode D1 is normally included to protect the l.e.d. against signals of the wrong polarity, but it is doubtful if it is of any real benefit.

Resistors R2 and R3 are respectively the load resistors for the common emitter output stage and the buffer amplifier. The output signal from pin 6 of IC1 is the correct polarity, and it can therefore drive the MIDI input of the game port without using any further signal processing.

Thru Port

Resistors R4, R5, and socket SK2 provide an optional Thru Port facility. This is simply an output that provides a replica of the input signal. It is common for PC MIDI software to include a Thru facility, which sends a copy of the input signal to the PC's MIDI output.

This method can be better in some circumstances, but it is useful to have a genuine Thru socket, and it requires few additional components. The circuit only requires a few milliamps of supply current, and this is obtained from the game port's supply pins.

No doubt the unit could be built as a MIDI lead with a box of tricks in the middle to handle the interfacing, but it is probably best to construct the unit as an add-on interface having sockets at the MIDI input and the Thru output. The unit is then connected to the rest of the system using standard MIDI leads.

The MIDI output socket and additional resistor can, of course, be included in the interface. PL1 is a 15-way male D-connector at the end of a captive lead. Three-way screened cable is sufficient, with the screen carrying the ground connection to pin 4 of PL1. This cable should be no more than about one metre long.

Troubleshooting

A simple way of checking that the interface is working is to temporarily connect an l.e.d. across Thru socket SK2. Connect the anode (a) of the l.e.d. to pin 4 and the cathode (k) to pin 5.

With everything connected up and switched on, playing the instrument connected to the MIDI input should result in flashes from the l.e.d. The pulses in a MIDI signal are very brief, so the flashes might not look very bright. Using a facility that produces masses of data should produce a more obvious response from the l.e.d. Pitch bend and some form of after-touch are two good ways of producing masses of MIDI data from a suitable instrument.

Installation

A lack of response when using MIDI recording and play software is more likely to be due to installation problems than a fault in the simple hardware of the interface. Having the MIDI interface hardware in place is not enough, and it must be correctly installed in Windows.

The MIDI port is often installed by default together with the other drivers for the sound system, but it sometimes has to be installed separately. The instruction manual for your PC or soundcard should make it clear if the MIDI port requires separate installation, and where appropriate there should be detailed installation instructions.

It is useful to check Device Manager for problems. First, go to the Start menu, select Settings and then Control Panel from the sub-menu. Next double-click on the System icon and then operate the Device Manager tab in the new window that opens.

Double-click on the icon for Sound, video and game controllers to expand it, and this should produce something like Fig.4. The number of entries here depends on the particular hardware in the PC, but there will usually be an entry for an MPU-401 compatible device if the MIDI interface is installed. Modern soundcards emulate the old Roland MPU-401 MIDI interface card, and the MIDI ports therefore appear in Device Manager as an MPU-401 compatible device.

If this entry is present but there is a yellow exclamation mark against it, either the hardware on the soundcard is faulty or the device drivers have not been installed correctly. Try deleting the entry for the port and reinstalling it. Either the device drivers or the hardware is faulty if the MIDI port cannot be installed properly.

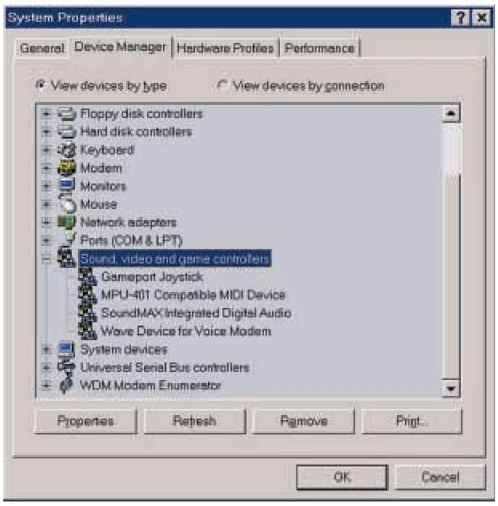


Fig.4. There should be an MPU-401 entry in Device Manager if the MIDI interface is installed.

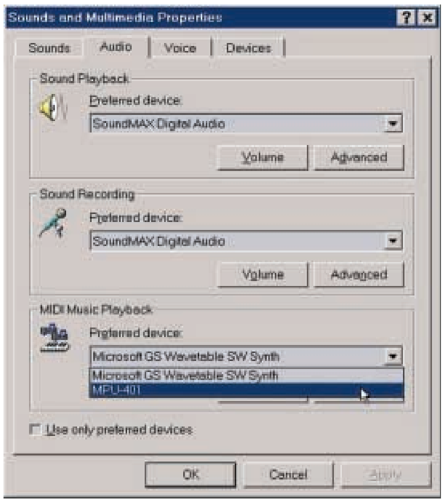


Fig.5. Selecting the MIDI port for MIDI playback.

If there are no problems indicated in Device Manager, check that the applications software is set up correctly. For example, by default the soundcard's built-in synthesiser rather than the MIDI port is normally used to play back MIDI files.

The sequencer program will probably have a facility that permits the playback device to be altered, or the default playback device can be changed using the built-in facilities of Windows. Go to the Control Panel and double-click on the Sounds and Multimedia icon. Then operate the Audio tab in the window that appears.

Towards the bottom of this window there should be a menu where the required MIDI playback device can be selected (see Fig.5). With some soundcards the MIDI port does not have a separate entry in Device Manager, but there should always be an MPU-401 playback option here if the port is installed in Windows.

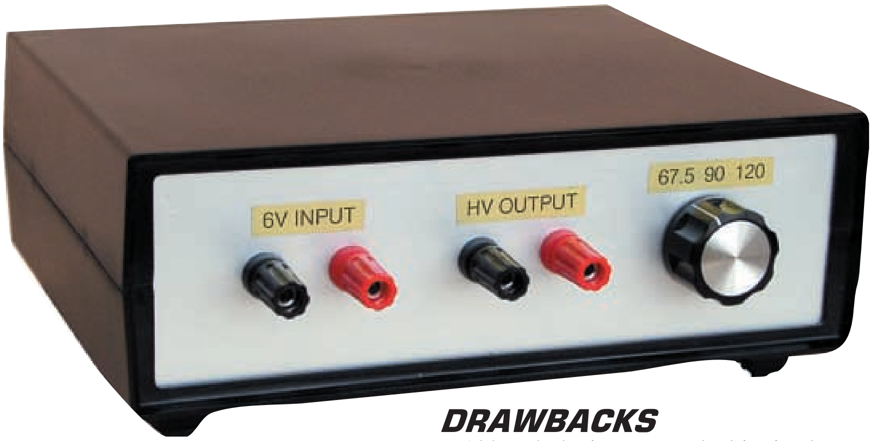
One final point worth noting is that the built-in MIDI ports of many motherboards are disabled by default. This is done to avoid wasting system resources on hardware that most users do not require. In some cases the MIDI interface can be enabled by adjusting a jumper on the motherboard, but in most cases it is enabled via the BIOS Setup program.

Constructional Project

HT POWER SUPPLY

ROBERT PENFOLD

Have you got the "bottle" for it?



THIS power supply unit is primarily designed for use with battery powered valve radios that require a high tension (HT) supply of about 90 volts at a current consumption of up to 10 milliamps or so. The batteries for these receivers are now unobtainable, and they were pretty expensive when it was possible to buy them.

The solution used here is to have a d.c. to d.c. converter that steps-up the output from a 6V battery to about 90V. Unfortunately, a voltage step-up is inevitably accompanied by a step-down in current. The practical importance of this is that the current drain from the 6V supply is much higher than the output current to the receiver.

With a theoretically perfect circuit there would be a fifteen-fold increase in the input current to match the fifteen-fold step-up in voltage. In practice there are significant losses in the circuit, and the input current is likely to be closer to 30 times the output current.

PRACTICAL PROPOSITION

Even so, 6V at a relatively high current is a more practical proposition than 90V at a modest power where battery operation is required. Ninety volts can be provided direct from batteries using something like ten PP3 size 9V batteries wired in series, but this is far from ideal.

Many simple valve radios only draw a few milliamps from the HT supply. This power supply, plus something like four C or D-size cells in series, are then practical as the power source. In fact, four humble AA cells are adequate with some receivers. With sets that require 10mA or so the current drain from the 6V supply is quite high at around 250mA to 300mA, and some form of rechargeable battery is then preferable.

Although primarily designed to provide an output potential of 90V, the power supply unit has additional output potentials of 67·5V and 120V, which are also used with small valve radios. The maximum output current at 120V is somewhat reduced, but currents of up to about 8mA are available. The unit may be usable in other applications that require a high voltage at low supply currents, but it has only been tested with simple valve radios.

STEPPING UP

One way of tackling this type of voltage conversion is to use a switch-mode power supply chip in the step-up mode. However, a step-up from just 6V to 90V and 120V is stretching things slightly with a supply of this type. Also, the high speed switching used in this type of circuit can generate radio frequency interference, which is clearly undesirable in this application.

The simpler alternative is to use a standard inverter circuit based on a 50Hz oscillator and a step-up transformer. The high voltage a.c. output from the transformer is rectified and smoothed to produce the high voltage d.c. output. For safety reasons, modern mains transformers use separate formers for the primary and secondary windings. As a consequence of this they work just as well if used in reverse as step-up transformers.

Note that what is normally the mains primary winding is referred to in this article as the secondary winding, which is its role in this application. Similarly, the low voltage secondary winding is called the primary winding here, since that is its function in this circuit.

DRAWBACKS

Although the inverter method is simple and inexpensive, it does have two or three drawbacks. One of these is that the final output voltage varies considerably with changes in loading and the input voltage.

Experience has shown that the output voltage from 90V batteries was not particularly stable either. The output potential actually varied from about 100V when new down to about 70V when nearing exhaustion. While not desirable, a lack of accuracy in the output voltage of the supply is not too important either.

Another problem is the difficulty involved in obtaining several switched output voltages. In the absence of a transformer having several step-up ratios, some extra electronics is needed in order to provide the extra voltages. The third problem is a lack of efficiency. Simple inverter units tend to consume high input currents even if only a modest output current is being drawn.

HOW IT WORKS

The circuit finally evolved is based on a simple inverter, but it also uses switch-mode power supply techniques to control the output voltage and give improved efficiency with low output currents. The block diagram for the HT Power Supply is shown

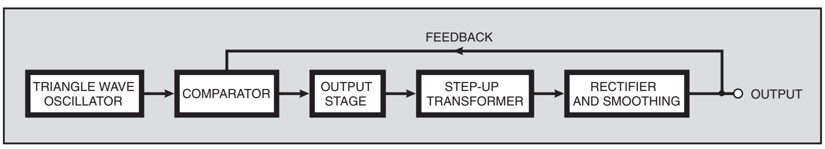


Fig.1. Block diagram for the HT Power Supply.

in Fig.1. The triangular oscillator and the comparator form a standard pulse width modulator, and the waveforms of Fig.2 help to explain the way in which this functions.

The pairs of waveforms represent the output signals of the triangular oscillator and voltage comparator stages. The triangular signal is fed to the non-inverting input of the comparator and a control voltage is applied to the inverting input. In Fig.2 the line through each triangular waveform represents the control voltage. The output from the comparator goes high when the triangular waveform is at the higher potential, and low when the control voltage is at the greater potential.

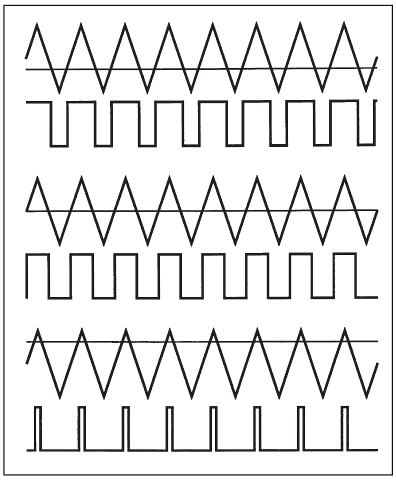


Fig.2. Example pulse width modulation (p.w.m.) waveforms.

Initially the control voltage is set quite low, giving an output from the comparator similar to the one in the top pair of waveforms. The comparator drives the primary winding of the step-up transformer via an output stage that can provide the relatively high drive currents involved here.

A rectifier and smoothing circuit processes the a.c. output signal of the transformer to produce a high voltage d.c. supply. Some of this voltage is fed back to the inverting input of the comparator, and as the output potential rises the voltage at the inverting input increases slightly as well. At first this has little effect, with a squarewave output being produced, as in the middle pair of waveforms in Fig.2. As the output voltage increases further the output signal from the comparator becomes a train of narrow pulses, as in the bottom pair of waveforms in Fig.2.

This gives a form of negative feedback that tends to stabilise the output voltage at a certain level. With the output only lightly loaded the output waveform becomes a series of very narrow pulses that result in little power being fed to the transformer. At times the voltage at the inverting input of the comparator may even go above the peak potential in the triangular signal, resulting in the signal to the transformer being cut off.

With the output loaded more heavily the output voltage reduces, but the power fed to the transformer is then increased. This resists the fall in output voltage, keeping the voltage drop to a minimum. The regulation efficiency of this set-up is not very good, but as pointed out previously, highly stable output potentials are not really needed in this application.

A big advantage of this system is that it gives good efficiency at all output currents. With low output currents only brief pulses are fed to the transformer, giving a low average input current. As the load on the output is increased, the length of the pulses increases as well, giving a higher average input current. The input current therefore rises and falls in proportion to changes in the loading, avoiding large amounts of wasted power at low output currents.

Another advantage is that the output voltage is easily controlled. The feedback limits the maximum output voltage, and the more feedback that is used, the lower the maximum output voltage that can be achieved. With lower output voltages shorter pulses are needed to maintain the output potential at a given load current, and good efficiency is still obtained.

CIRCUIT OPERATION

The full circuit diagram for the HT Power Supply appears in Fig.3. Dual op.amp IC1 is used in the triangular oscillator, which is a conventional design having IC1a as the integrator and IC1b as the trigger circuit. A squarewave signal is produced at the output of IC1b and a triangular signal is available from IC1a, but it is only the triangular signal that is needed in this application.

The transformer provides optimum results at a low frequency of around 50Hz to 70Hz. Timing components resistor R5 and capacitor C4 set the output frequency at about 65Hz.

A PMOS operational amplifier, IC2, is used here as the voltage comparator. The output of IC1a connects direct to the non-inverting input, pin 3, while resistors R6 and R7 provide an initial bias voltage to the inverting input at pin 2.

The output of IC2 drives the primary winding of step-up transformer T1 via common emitter switching transistor TR1.

The drive current to TR1 is less than a milliamp, but this is a power Darlington device that has a very high current gain. It is, therefore, able to supply a current of a few hundred milliamps to the primary winding of T1 (remember secondary equals primary here – see earlier note).

The secondary (primary) winding of T1 drives a full-wave bridge rectifier (diodes D1 to D4) and smoothing capacitor C5. Further smoothing is required, and resistor R10 plus the series capacitance of C7 and C8 provide this. A smoothing capacitor having a value of 220μF and a maximum voltage rating of 200V is needed, but a suitable component does not seem to be available. Instead, two 470μF 100V capacitors wired in series are used. These provide a capacitance of 235μF and a maximum working voltage approaching 200V. Resistors R11 and R12 ensure that capacitors C7 and C8 more or less evenly share the output voltage.

Negative feedback is provided by way of diode D5, resistor R9, and whichever of the three preset potentiometers (resistors), VR1 to VR3, is selected using switch S1. The presets control the amount of negative feedback and they are adjusted to produce the required output voltages.

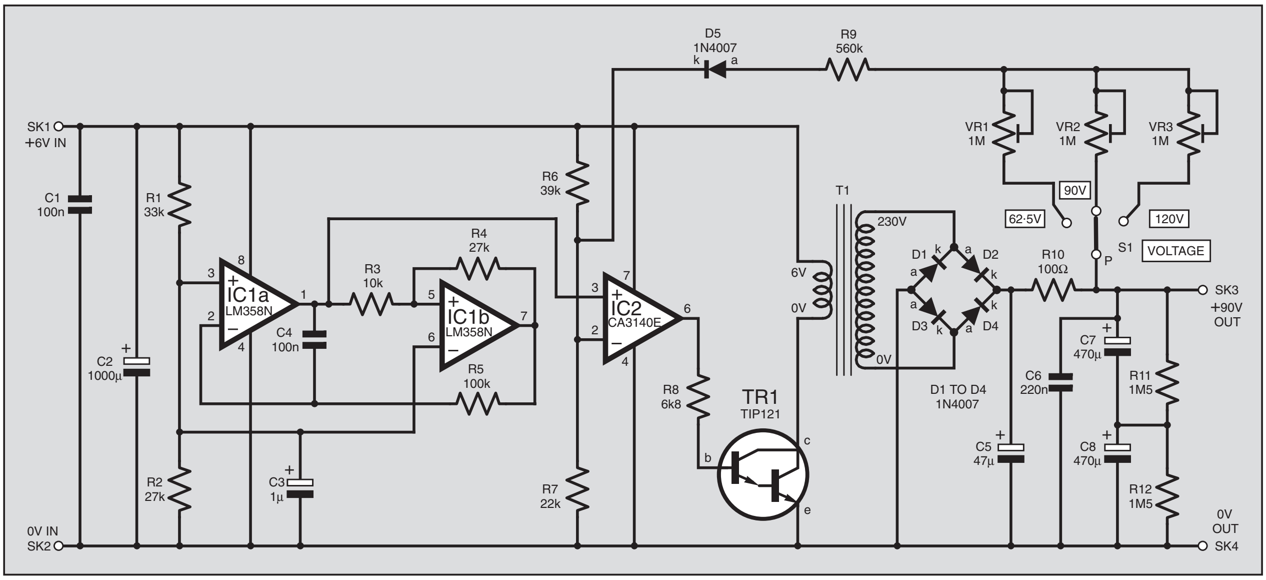


Fig.3. Complete circuit diagram for the HT Power Supply for use with battery powered valve radios.

CONSTRUCTION

The HT Power Supply is built on a piece of stripboard and the component layout, hard wiring and details of breaks required in the copper strips on the underside of the board are shown in Fig.4. The board has 36 holes by 39 copper strips, and it can conveniently be cut from one of the standard size boards that have 39 copper strips.

Stripboard is easily cut using a hacksaw or junior hacksaw, but use no more than moderate pressure since some stripboards are quite brittle. The three mounting holes are 3mm dia. and will accept metric M2·5 mounting bolts.

The breaks in the copper strips can be made using a special tool or a twist drill bit of about 5mm dia. Make sure that the strips are cut across their full widths, but do not cut so deeply into the board that it is weakened.

Next, the link-wires and components can be added to the board. The CA3140E used for IC2 has a PMOS input stage and therefore requires the standard anti-static handling precautions. The most important of these is to fit it on the board via a holder. The LM358N used for IC1 is not vulnerable to static charges but it is also advisable to use a holder for this device.

Do not fit IC2 until the board and all the hard wiring has been completed, and try to touch the pins as little as possible. Keep this component away from any likely sources of static electricity once it has been removed from the anti-static packaging.

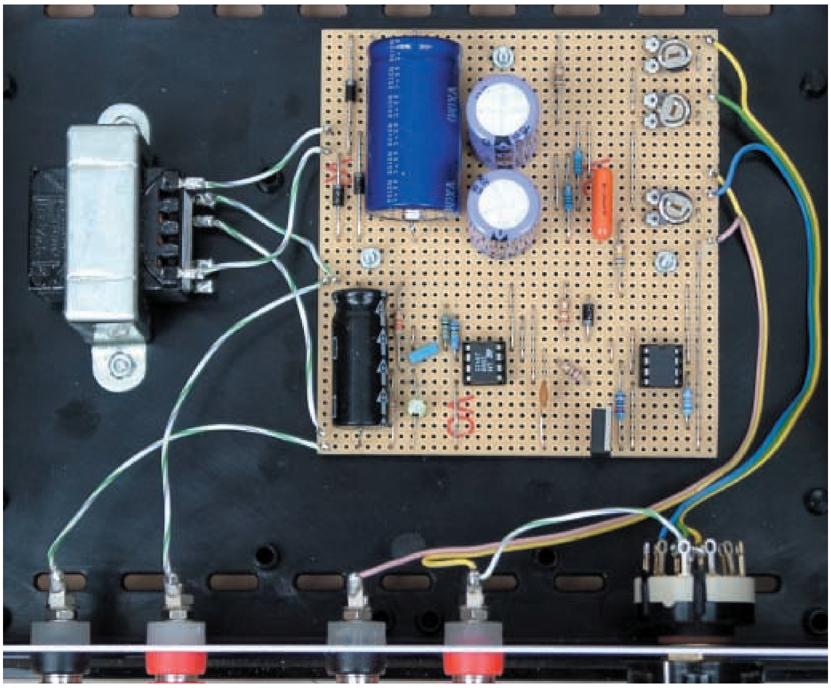
The link-wires are made from 24s.w.g. (0·56mm) tinned copper wire. Some of the link-wires are quite long and should be insulated with pieces of sleeving to ensure that there are no accidental short circuits. Transistor TR1 is a power device, but in this circuit it does not dissipate much power, and no heatsink is required.

Capacitor C4 should be a type having 5mm (0·2-inch) lead spacing, and it should then fit easily into this layout. Capacitor C5 must have a working voltage of 200V or more. Unfortunately, you are not exactly "spoilt for choice" with high voltage electrolytic capacitors, and it will probably be necessary to use a component having a much higher voltage rating of 350V or 450V.

This component will probably be quite large, but the component layout has been designed to accommodate a large axial lead capacitor. A radial lead capacitor will probably not fit easily into this layout. Make quite sure that electrolytic capacitors C2, C5, C7 and C8 are all fitted into the board with their correct polarity. Mistakes here could cause costly damage and could even be dangerous.

BOXING UP

The prototype is housed in a slightly oversized instrument case, and a medium size case or one of the larger metal or plastic boxes is adequate to accommodate everything. It is assumed here that the 6V battery will be a large external type. If the unit is powered from internal batteries a suitably large case will be needed, and a suitable on/off toggle switch must be added into the positive battery lead. Sockets SK1 and SK2 will then be unnecessary.



Interwiring from the circuit board to the front panel mounted components and the "step-up" transformer.

COMPONENTS

See SHOP TALK page

Resistors

R1	33k
R2, R4	27k (2 off)
R3	10k
R5	100k
R6	39k
R7	22k
R8	6k8
R9	560k
R10	100Ω
R11,R12	1M5 (2 off)

All 0·25W 5% carbon film

Potentiometers

VR1,VR2, VR3	1M min. carbon preset , horizontal (3 off)

Capacitors

C1	100n ceramic
C2	1000μ axial elect. 10V
C3	1μ radial elect. 63V
C4	100n polyester
C5	47μ axial elect. 450V
C6	220n polyester, 250V
C7,C8	470μ radial elect. 100V (2 off)

Semiconductors

D1 to D5	1N4007 1A 1000V rectifier (5 off)
IC1	LM358N dual op.amp
IC2	CA3140E PMOS op.amp
TR1	TIP121 or TIP122 *npn* power Darlington

Miscellaneous

SK1,SK3	4mm terminal post (red – 2 off)
SK2,SK4	4mm terminal post (black – 2 off)
T1	Standard 230V mains transformer, with twin 6V 500mA secondaries (see text)
S1	1-pole12-way rotary switch, with end-stop set for 3-way operation

Medium size instrument case, see text; 0·1-inch matrix stripboard, size 36 holes by 39 strips; 8-pin d.i.l. holder (2 off); control knob; multistrand connecting wire; solder pins; solder; fixings, etc.

Approx. Cost Guidance Only* £20 *excluding batts & case

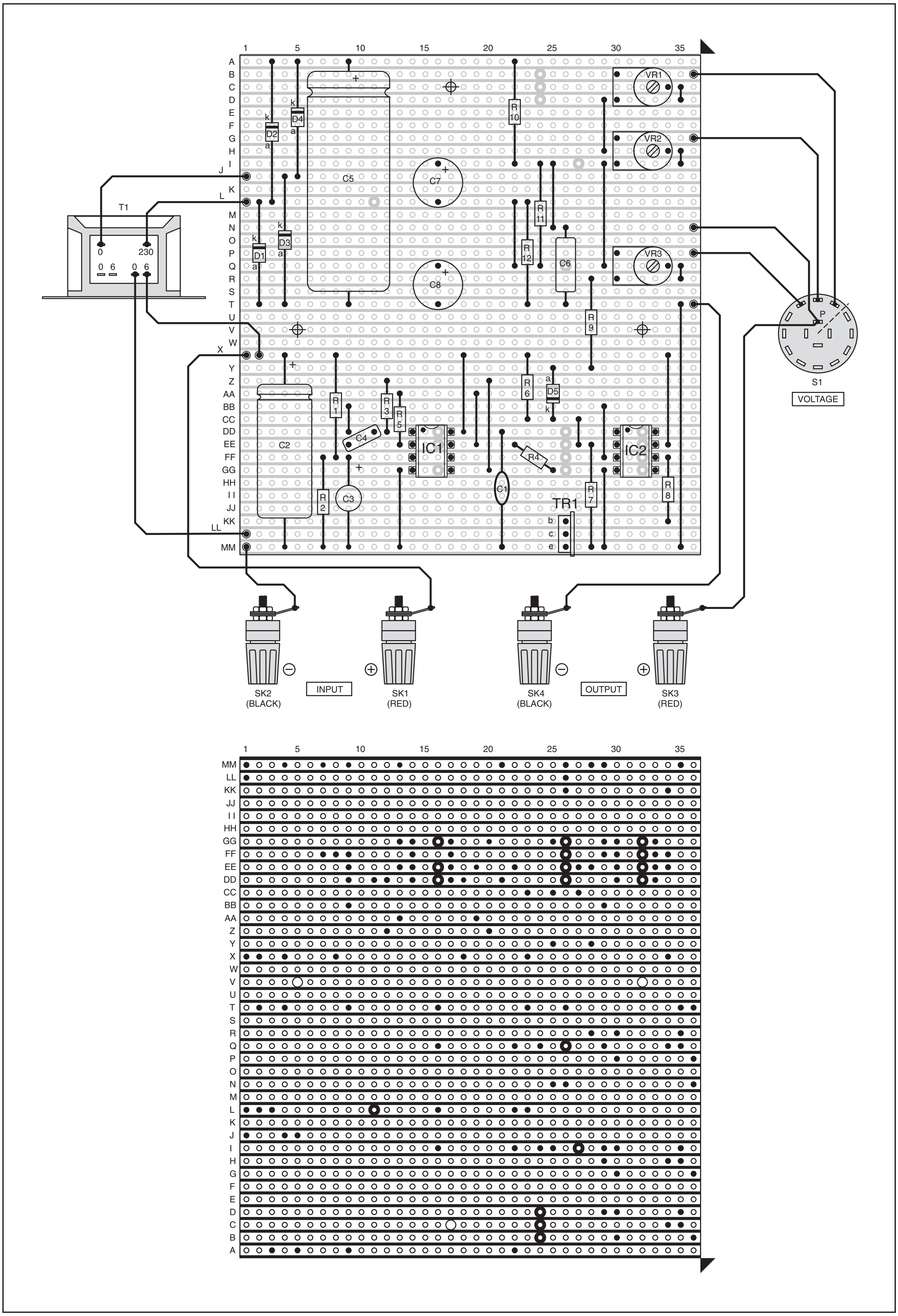


Fig.4. Stripboard topside component layout, interwiring and details of underside copper track breaks.

There is no sensitive wiring so the layout of the unit is not critical. The circuit board is mounted on the base panel of the case using M2·5 fixings, which should include spacers about 6mm or more in length. This is especially important if a metal case is used, as a gap of at least a few millimetres is then needed between the high voltage connections on the underside of the board and the case.

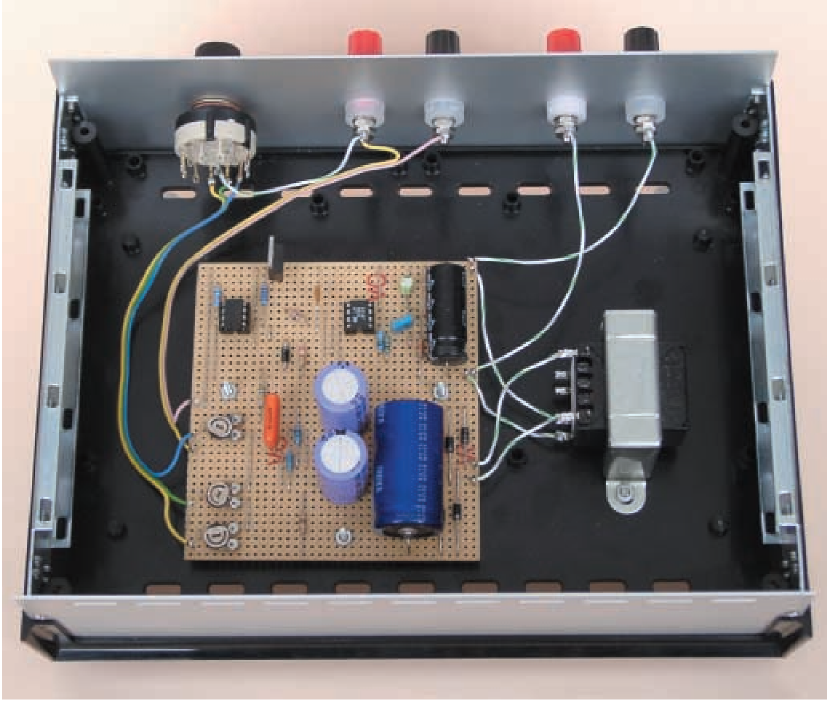
Transformer T1 can be a type rated at 3V–0V–3V at 100mA if output currents of no more than about two or three milliamps are required. The centre tap (0V) is ignored and the input signal is applied to the two 3V leads.

For higher output currents a transformer having twin 6V 500mA windings is required. In order to obtain the highest possible output current at 120V the two windings can be used in parallel. In other words, wire the two 0V tags together and also connect the two 6V tags together. For most purposes though, only one of the windings is needed and the other one can be left unconnected.

Terminal posts are used as for the input and output sockets on the prototype. These can be connected to bare wires and they will also accept 4mm plugs. However, any sockets that are appropriate for a power supply can be used.

Switch S1 is a 12-way single-pole rotary switch having an adjustable end-stop, which is set for 3-way operation in this case. Alternatively, a 3-way 4-pole switch can be used, with three sections of the switch being left unused.

With everything fitted in the case the small amount of hard wiring is added. This wiring is also included in Fig.4. The unit should then be given a thorough check for errors prior to testing.



Completed unit showing positioning of components and circuit board inside the metal instrument case.

ADJUSTMENTS

A multimeter is needed in order to set the correct output voltages, but even the cheapest of digital or analogue instruments will suffice. The multimeter is connected across sockets SK3 and SK4, and should be set to a suitably high voltage range, such as the 199·9V range on a digital type. Initially all three presets (VR1 to VR3) should be set for minimum output voltage, or fully counter-clockwise in other words.

After a final check of the wiring connect the 6V battery to sockets SK1 and SK2, being careful to get the polarity correct. The voltage indicated by the multimeter should build fairly rapidly to around 60V. If it does not, disconnect the battery immediately and thoroughly check the wiring, etc. for errors.

If all is well the presets can be set for the correct voltages. The loaded output voltages will be significantly different to the unloaded voltages, especially when high output currents are drawn. Therefore, it is best to set each output potential with the unit powering the appropriate radio receiver. It can take as much as a few seconds for the output voltage to fully respond to changes in the settings of the presets, so wait for the reading to stabilise after each adjustment has been made.

The prototype was set for output voltages of 67·5V, 90V and 120V, but the presets can be set for any desired output potentials from about 60V to 120V. You can also have the presets set for the same output potential, but with different levels of loading, so that (say) two 90V receivers can both be operated with the optimum supply potential.

The output voltage of the unit is not dangerously high even when set to 120V. However, it can supply a *noticeable electric shock,* and the output of the unit should be treated with *due respect*. □

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READOUT

E-mail: editorial@epemag.wimborne.co.uk

John Becker addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

WIN A DIGITAL MULTIMETER

A $3\frac{1}{2}$ digit pocket-sized l.c.d. multimeter which measures a.c. and d.c. voltage, d.c. current and resistance. It can also test diodes and bipolar transistors.

Every month we will give a Digital Multimeter to the author of the best *Readout* letter.

★ LETTER OF THE MONTH ★

ELECTRONIC EPE, PLUS EMPLOYMENT

Dear EPE,

Reading your magazine and letters prompts me to write. This year I have purchased two electronic subscriptions to magazines, one for *EPE* and one for *Circuit Cellar*. I have also purchased *EPE* back copies (electronically) and *EPE* CD-ROMS. The service provides an immediate response for which I thank you.

The reason for purchasing electronically is simple – firstly the cost is much lower than obtaining the written copy, secondly being in Singapore I do not have to wait for shipment, and thirdly the content is very suitable to further understanding and updating on the level of technology you provide. Most important, the level of service is high with the response – we order, pay by credit/debit card, and either download or within 10 days receive the CD.

Having brand names etc. does not sell in this field. For example, although I am interested in programming, I do not buy Microsoft magazines as the articles are not relevant.

I also notice the increased mailage from people regarding electronics employment. Having lived in Asia for nearly 40 years (I am from UK coming over here initially at 19 during the Indonesian *confronsi*) and having worked for British, Danish and German owned companies, plus my own small business, my advice to all is simple – nobody has the *right* to work, only the *opportunity* – remember even human rights activist groups are also being funded and staff is paid (employed).

Business has only one mission – to make money i.e. shareholders expect a return – all other objectives, tasks etc. are orientated to this – if staffing costs 10% of product any drop in product (e.g. from 100% to 80% means quite simply reduction of staffing costs by 20%. For some firms this may mean pay cuts by 10% to 20%, for others to trim staff by this amount plus possible pay cuts for remainder.

Back to *EPE* – in the March '01 issue, the article under *Interface* on ADC mentioned the availability of Visual Basic software. However, having checked this out I cannot find it. Can you please advise the location. Also, in the electronic download for November, I could not find the 16-page supplement for *PIC Toolkit TK3* – can you advise?

Once again I would like to thank you for a good Technology magazine.

William Rance, Singapore, via email

Thanks William for your appreciation, and for the observations on what (regrettably?) are the commercial facts of life.

Visual Basic as such is not available from us, it needs to be bought through normal software supply outlets. However, the program routines written by Robert Penfold for his Interface *articles are available either on disk (Interface Disk 1) from the Editorial office (a small handling charge applies – see PCB Service page of any issue), or as free downloads via our ftp site (look for folder named Interface).*

The TK3 supplement is available electronically (and free) via our Online site, browse the Library.

ONLINE AND INTERFACING

Dear EPE,

Thank you for your compact Online editions. Compared to a US mag, weighing in at between 16 and 20 Mbytes, *EPE* has always been between 4 and 5 Mbytes. I have learnt a lot from Robert Penfold's *Interface* pages, which are short and sweet, to the point and with valuable information. I find the examples are always adaptable so that I can implement the concepts to suit my needs.

I would greatly appreciate an article or tutorial series by Robert Penfold and/or John Becker dealing with the basics, not tangled in a huge project, on interfacing VB6 to various PIC devices (i.e. how would I implement setting a number on a VB6 screen and then send it through to the PIC using RS232 standards. This could be used in the same way as a keypad connected directly to a PIC port, but VB6 gives a better user interface for certain applications.

I am also interested in motion control (PID) and would like to see a tutorial or practical article on using the PWM within a PIC16Fxxx for servo control of a motor.

Daryn Smith, Port Elizabeth, South Africa, via email

Yes, Daryn, we know that our electronic editions are good value (as are the paper editions, of course!)

To do a PC-PIC RS232 interface would certainly be possible and perhaps Robert or I might one day do one if other readers tell us they'd find it useful. PID (Proportional plus Integral plus Derivative) devices, though, are unlikely to find wide readership appeal and are probably not something that we shall cover (although the subject has been covered in the Supplements of our sister publication Modern Electronics Manual *– email us if you'd like more information on* MEM. *The printed Base Manual is no longer available but we are working on a CD-ROM version).*

TK3 AND 640 x 480

Dear EPE,

I am referring to the way that the right hand side and bottom of the main title screen is hidden (only half of the boxes can be seen).

I am glad to see *PIC Polywhatsit* (Dec '01). I just happened to see your Oct 1989 article on the same subject as I was going through my books recently, while looking for some info.

Mike MacLeod, Mossel Bay, South Africa, via the Net

Most screens now have multiple display size options available via the Control Panel, as I discuss in the original text. Older screens like your 640 × 480 can never show the full TK3 screen, but all the essential data is still visible.

Glad you appreciate PolyW!

PCLATH

Dear EPE,

I suggest that you may want to disseminate the issues around PCLATH that were recently discussed on your *Chat Zone*. They could have a profound effect on program operation. If anyone plans to use more than the first 2K of program memory in, say, the now ubiquitous PIC16F877, then they *must* understand the implications of setting the upper five bits in the program counter.

The "call" and "goto" instructions only set the lower eight bits of the program counter. If such an instruction is called from the first 2K of program memory to a label in the second 2K, then the program will not work correctly as it will set the program counter to the label address, assuming its upper byte is still zero. The best outcome is that the program will appear to stop, and that will be obvious to the user. The worst outcome is that the program will do something that is plausible but incorrect, and the user will not notice.

The remedy is to set the upper byte of the label address into PCLATH prior to executing the "call" or "goto", and all will be well. The "HIGH" operator in MPASM may be used to do this during assembly, as given almost as a "throw-away" line in the Microchip Mid-Range manual. In the absence of the "HIGH" operator I have been trying to think how this might be done automatically, and it goes something like this:

1. Assemble the code as if the upper byte problem does not exist.

2. Parse the listing and identify where program bank/page boundaries are crossed by "call" or "goto" instructions. For each such instance add code to set PCLATH (two instructions).

3. Assemble the code again, potentially with a new lot of label addresses.

4. Parse the listing and identify if any new unsatisfied boundary crossing problems arose and check whether previously-set PCLATH instructions are now invalid. If yes, correct the errors and go back to step 3; if no, exit.

Hopefully this process would converge!

A safer alternative is to always include the two PCLATH-setting instructions, whether they are needed or not, and set them correctly from the listing after assembly. This is implied by the Microchip Mid-Range manual in that one of the two instructions is "MOVLW HIGH (address of destination label)" and the second is "MOVWF PCLATH". For safety's sake, they should always be included. Without the benefit of the "HIGH" operator, of course, the user makes the necessary changes after assembly, then re-assembles once only.

A compromise is to (mentally) use "near" and "far" "call" and "goto" instructions. For example, a delay loop would use a "near" "goto", that is, without the two PCLATH instructions, always checking that the whole of the delay function is within a given page/bank. Of course, adding two instructions changes the value of the delay!

John Waller, via email

Since receiving John's email I have been in considerable contact with him. As a result he has agreed to write a feature article on PCLATH in more depth. He has also been "field-testing" my PCLATH upgrades to TK3 to which I refer in my reply to Alan Raistrick (see next page).

A SENSE OF EXCELLENCE

Dear EPE,

I think the current *Teach-In 2002* series on sensors is an excellent idea for a tutorial series and I look forward to working through the course. Having played with the Pico ADC-40, I couldn't get it to playback a signal in real time once it has been recorded (e.g. showing a voltage creep up to a threshold level then back down again). This would be useful for demonstration purposes. Do you know if this is possible?

Brett Lowery, via email

Alan Winstanley, one of the three co-authors of TI *responded to Brett:*

Many thanks for your encouraging comments about *Teach-In 2002*.

I don't think the Picoscope can automatically play back real-time data in graphical form *per se*. You have an option to monitor the waveform as a traditional CRO or as a chart recorder during the display mode. Click F5 in the Picoscope, then check Slow Sampling settings to choose.

However, you can use PicoLog to capture data which can be exported into a spreadsheet. PicoLog Player will also open up a saved session for you to view as a waveform after the event, but you have to advance the waveform manually using the mouse. I think I'm right in saying it won't play back on its own.

Use PicoLog Recorder to capture data, then File/Save As a .PLW file. Then in PicoLog Player, go File/Open and open the data file. Still in PicoLog Player, click the little button on the right (a red zig-zag graph) to open the Graphical Display option. Click the button on the right, a little black Tick (options) - then choose "Scroll" for the time axis units. After which you can use the Forward/Backward arrows in the player controls to advance the waveform 1/4 of the display each click.

Not quite what you're looking for but it may be of help.

Instead of clicking that Graph button (red zig-zag), you can also click the button to its right, which opens a simple table of data. You can copy and paste this into Excel to make your own graphs.

Alan Winstanley

TUTORIALS AND TK3

Dear EPE,

I am slightly confused about the relationship between the *PICtutor* and *PIC Toolkit Mk1/2/3* boards available. I am new to PICs and would like to use John Becker's tutorial CD-ROM to make a start in understanding them. The PICtutor Hardware (deluxe) is priced at £99 + VAT from Wimborne. Magenta seem to do a similar *PIC Tutor* board for about £75 (incl. VAT). Is there any major difference in functionality, or is it just price competition?

I like the look of the new *PIC Toolkit Mk3*. It appears to be much more versatile than the *PICtutor* hardware, and has a better interface to the *Toolkit TK3*. Is this board appropriate for use with the *PICtutor* CD-ROM, albeit with fewer l.e.d.s and no l.e.d. 7-segment display? This board, and the TK3 software, seem to be a much better option in the long run. In other words, what problems can I expect if I purchase the *PICtutor* CD-ROM and the *Toolkit Mk3/TK3* software and board?

**David Brown, CEng MIEE,
via email**

Thanks for you comments David. PICtutor *is a board through which you experiment with my Tutorial exercises on the CD-ROM. It is not intended for use with* Toolkit *software. The* Toolkits *(of which only* Mk3/TK3 *is recommended now), are programming boards for use by more experienced constructors. The Magenta board is their version of the original* PIC Tutorial *board published in* EPE *Mar-May '98. It is not an alternative to the* PICtutor *board.*

TK3 AND CODE PROTECTION

Dear EPE,

Whilst the *Toolkit TK3* assembler can have Config data included in its source (ASM) code it cannot have EEPROM data included in it. Ok, no problem, send it to the PIC separately. MPASM, however, can produce HEX files containing Config and EEPROM data, and the Send Hex button of TK3 can cope with this. But there is a problem if code protection is set in the HEX file.

During assembly MPASM sorts the HEX file into the following order:

Program code ($0000-$1FFF)
ID ($2000-$2003)
Config ($2007)
EEPROM ($2100-$21FF)

You will notice that it is sorted into ascending order of addresses. Program code is sent first, then ID (if specified), then Config, and herein lies the problem. The code protection being set instantly prevents any further programming, so if the HEX file includes EEPROM data, that data cannot be programmed.

A work-around is to change the source or HEX file to unprotected code then manually set code protection after programming using the Send/Read Config data button.

Peter Hemsley, via email

Thanks for the observations, Peter – you are a gold-mine of useful PIC info. Readers, there are several of Peter's helpful program routines on our ftp site in the PIC Tricks folder.

Sometime I may well give TK3 the ability to handle data statements intended for the Data EEPROM. Such a facility would have been useful when developing my PIC Magick Musick *(Jan '02), allowing "tunes" to be imported as .INC files during assembly. Using the Send Message option, however, was quite satisfactory.*

PICS WELL ARMED

Dear EPE,

Toolkit TK3 (Oct-Nov '01) looks an extremely useful piece of programming. A great deal of work and thought has obviously gone into it. I'll bet you got through some stock of coffee on the late nights sorting out the problems. It is very brave of you to put your code available for us all to look at.

Many thanks as well for the two Microchip CDs with October '01 issue. In spite of being an electronic subscriber to *EPE* I actually bought a paper copy to get the CDs. I know it is all available on their website, but the time I've spent finding things on the CDs would have cost an arm and a leg on the Internet.

**Alan S. Raistrick,
via email**

TK3 actually became a hobby for me for many months and I enjoyed adding the various facilities. Since publication I've been adding more still, basically to improve the ease of what I do with it, but which I shall release to you all in due course. One thing in particular I've added is to extend TK3's ability to use PCLATH more effectively.

The current version does not accept program addresses in excess of 2K, a matter I did not appreciate until trying to integrate two tables in excess of 1000 commands apiece into a PIC World Clock *graphics l.c.d. design I'm working on.*

And yes, coffee and late nights are frequently in use when writing complex software!

We felt extremely pleased that Microchip asked us to include their CD-ROMs with Oct '01. As you say, downloading such a wealth of material is costly and time consuming. Even though Microchip periodically update their CDs to include new devices, the essential information remains the same and is of long term benefit.

In practically all cases we make our own software freely available in the belief that people can learn about programming by studying the code.

KIRLIAN CAMERA

Dear EPE,

I am currently engaged on a Lakhovsky Multiple Wave Oscillator project. This consists of three separate sections, a normal PSU, a high voltage driver using a car ignition coil and a Tesla coil driving a pair of antenna. Over the last 30 years there have been many circuits, parts of which can be used but all have one or more unobtainable components. You may not believe this but a 60s' circuit used a Ford model T ignition coil, and I obtained a similar antique version.

I have built the Tesla coil after much difficulty in getting the gauge of wire and lists of American equivalents of Imperial s.w.g. I am continuing with the back end of a Kirlian Camera design from *PE* May 1989. (This was a delightful article, although I never built it.) Can you let me know where I might obtain a toroidal centre tap mains transformer 25V + 25V 1.6A (ILP Electronics 3X016).

Your Special Supplement on *The End to All Diseases* (Apr '01) was of great interest as this is the same area that Lokhovsky was working on.

**Mike Walker,
by email**

Your Kirlian project seems fascinating, Mike. One day I might dabble in such myself. In fact I was working with PE *when the '89 circuit was published and became intrigued with the idea as a result.*

ILP Transformers still exist – email: ***ilp@btinternet.com*** *or phone 01233 750481.*

CHEATS AGAIN

Dear EPE,

I am pleased to find that some readers are making use of my math routines, as Gerard Galvin is (Cheats Shifted, *Readout* Dec '01). I also see that Gerard realised that binary division uses the same technique as the decimal long division you were taught at school, it really is that simple. The same also applies to binary multiplication.

Going by the book is not always best. For instance, the subtraction method would be better for small numbers as only a few iterations are required. Gavin states that his routine takes 798 cycles to execute, so I spent ten minutes modifying my binary-to-decimal routine to 10 bits. Although not optimised it executes in 480 cycles, which is a saving of some 300 cycles, and the code is probably a lot smaller too. John says he'll put it on the PIC Tricks disk/folder.

**Peter Hemsley,
via email**

As indeed I have Peter. Thanks.

APPRECIABLE SKILLS

Dear EPE,

In the December issue is an email letter from Pat Walton in response to my earlier comments on skill shortages. Would you please forward to him my appreciation of his comments and perhaps also in your editorial make a plea for a response to overseas readers to express their views on the subject.

My local colleges tell me that when they try to run courses on technical subjects they get almost no entrants. I am advised that they cannot get sufficient enrolees to run courses on such as PLCs, for instance. Even at a local university they only offer electronics with another subject e.g. electronics and music (?) which I find a strange combination!

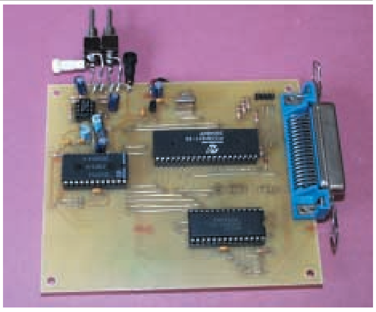
**Jim of Derby,
via email**

The question, then Jim, is why pupils at school are not being encouraged to think about pursuing electronics as a higher education subject and so subsequently enrol for appropriate college/university courses?

So what is the experience of our overseas readers regarding such matters?

PIC SPECTRUM ANALYSER

JOHN BECKER



Graphically displays frequency content of any waveform, using sophisticated, but automatic, mathematical analysis routines.

A SPECTRUM analyser is a sophisticated workshop tool that allows you to analyse a waveform of any shape and establish which frequencies it contains and at which relative amplitudes.

The design presented here analyses input signals up to about 50kHz and displays frequency content to around 400kHz. A signal interface board is controlled by a PIC microcontroller and outputs digitised data to a PC-compatible computer which analyses the data and displays it graphically on its VDU.

Such displays can assist in improving many types of electronic hardware design.

HARMONICS

By its nature and definition, a "pure" sinewave is comprised only of a single frequency. Other waveforms, although seemingly simple in appearance, are actually comprised of a whole variety of frequencies at different amplitudes. A frequency counter may show, for example, that a sinewave and a square wave are both occurring at the same given number of cycles per second, but it is the *fundamental* frequency of the waveforms to which the counter is responding. The counter ignores the numerous minor frequencies implicit in a square wave.

In non-sinusoidal waveforms, frequencies that occur in addition to the fundamental are known as *harmonics*. A pure sinewave has no harmonic frequencies. In other simple waveforms, the harmonics and their frequency distribution are directly related to the shape of the waveform. They are always at a higher frequency than the fundamental.

Harmonics are most abundant in square waves, non-existent in *pure* sinewaves (which are not sinewaves if they contain harmonics!) and progressively less abundant as a square wave becomes increasing filtered to become sinusoidal. Waveforms such as triangles, ramps and pulses all contain varying quantities of harmonics.

Complex waveforms, such as occur in speech and orchestral music for example, not only have specific harmonic contents at a given moment in time, but also vary their content across time. This can result in harmonics being created at frequencies *lower* than the various fundamentals.

SPECTRAL DISPLAY

The aim of a spectrum analyser is to analyse the "spectrum" of the harmonic frequencies occurring in waveforms, simple or complex, and display the contents in various graphical forms. With the abundance of computers, the most convenient form of display is via their screens.

Armed with such a display, and possibly a screen dump of it to a printer, the frequency content of any signal can be assessed. This allows, for instance, a designer to modify the design of an audio circuit, or perhaps the settings of a signal generator, so that the desired response can be tailored.

ANALYSIS TECHNIQUES

So far as is known, there are three ways in which frequency (spectrum) analysis can be performed. One is to use a bank of numerous filters, each responding to a different frequency. Another is to repeatedly feed a recorded signal through a variable filter whose narrow passband is swept across the full spectral range. Such techniques can achieve incredibly accurate results. They are, though, complex and expensive to build.

The third option, as used here, is to analyse waveforms mathematically once they have been sampled. There is a drawback, however, to analysing waveforms in this way compared to using filtering techniques.

Sampled waveforms consist of discrete data values taken at separate instants in time. As such, the sampling process itself introduces its own harmonics. These can be ignored when the input signal consists of frequencies well below the sampling frequency.

As the two become closer, though, the accuracy of analysis becomes less reliable. Although harmonic data will be displayed, it will become increasingly influenced by the sampling rate.

While the unit described here will accept input signals in excess of 50kHz, the analysis should be regarded as being more accurate for signals within the audio range.

FOURIER ANALYSIS

The theory of frequency analysis through mathematical techniques goes back to the early 1800's, although it took modern computing to come along to really make it a practical proposition.

French mathematician Jean-Babtiste Joseph Fourier (1768-1830) was the man

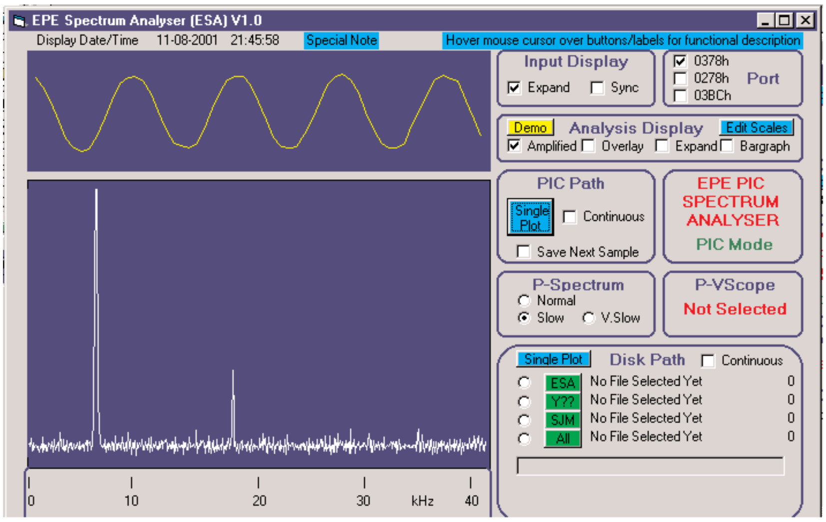


Fig.1. Spectral analysis of a poorly shaped sinewave.

who originated the idea, although variants of his technique have since evolved.

Fourier realised that a waveform could be analysed or broken down into component sinusoidal (sine or cosine) waves. Similarly, any waveform could be generated by combining selected quantities and amplitudes of these components. His technique is widely known as Fast Fourier Transform, FFT.

EXAMPLE WAVEFORMS

In Fig.2 is a shown a "screen dump" of the spectral graph for a sinewave generated by a computer and analysed by the Spectrum Analyser software. It shows a large single peak at the left. Its position horizontally shows that it is placed fairly low in the audio spectrum. In this instance, the display has not been related to any scale.

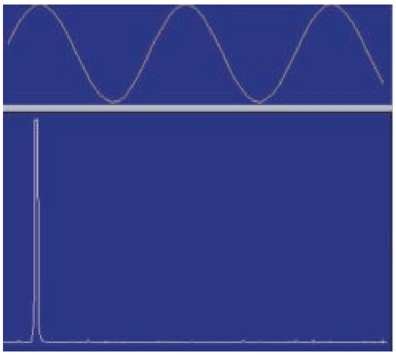


Fig.2. Analysis display for a pure sinewave.

The screen dump in Fig.1, though, shows the "real-time" analysis of an impure sinewave generated by a low-quality signal generator that has seen better days! Not only is the signal not truly sinusoidal, but it also has noise superimposed on it.

The signal frequency is nominally about 6kHz (main peak), but a very distinct secondary peak is seen at about 18kHz, reflecting the waveform's non-purity. There are also minor peaks across the range and most of these are associated with the signal's noise content, although at least one, at about 35kHz, could well be caused by the waveform. Had the signal been truly sinusoidal, only the lefthand peak would have been shown, as in Fig.2.

In Fig.3 is shown the analysis graph (on a broader display scale) for a square wave whose fundamental period is similar to that for the near-sinewave in Fig.1, but look at the harmonics now shown!

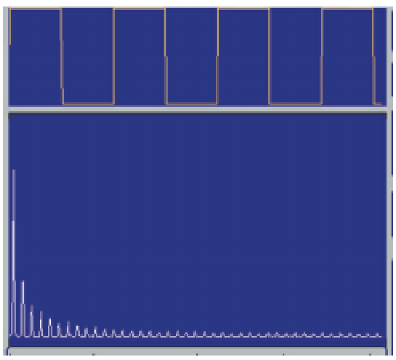


Fig.3. Harmonics contained in an analysed square wave.

The fundamental is shown to the far left, while the harmonics extend across the full range, steadily decreasing in amplitude. This illustrates the nature of harmonics, those closest to the fundamental frequency have the greatest amplitude. Those furthest away have the least.

As commented earlier, some of the harmonics will have been created by the sampling process itself, but most are due to the nature of square waves. Note also that the upper window shows how the sampling process has resulted in the edges of the square wave deviating slightly from the vertical.

The graph in Fig.4 shows a software-amplified display of the same analysis peaks. Those to the far left have been clipped to keep them within the bounds of the screen window.

Each harmonic has a direct relationship to the frequency of the fundamental and to other harmonics to either side of it. The reasoning is mathematical, though, and will not be discussed.

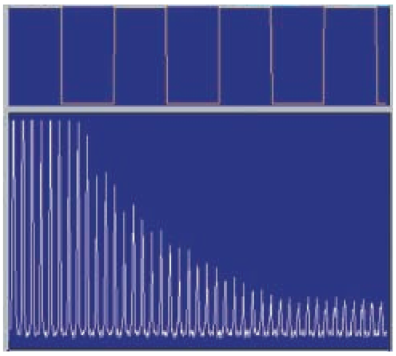


Fig.4. Amplified display of square wave harmonics.

HARDWARE INTERFACES

The software described later has been designed principally for use with the PIC Spectrum Analyser hardware presented here. However, by intention, it can also be interfaced to the *PIC Dual-Chan Virtual Scope (P-VScope)* – published in Oct '00 – without any modification to that design, although with a much lower frequency range.

As usual with many of the author's designs that interface external frequencies to a computer, the principle behind the PIC Spectrum Analyser hardware is that sampling is done at the fastest possible rate. The hardware temporarily stores it in a buffer memory, and signals to the PC when the buffer is full, in this case, after 32 kilobytes have been sampled.

On receipt of a signal from the interface, the PC extracts the data byte by byte, and stores it in its own memory. When the full block has been received, the PC signals to the interface to start taking the next batch of samples. The PC then performs its analysis and displays the results on screen. The overall maximum rate of processing depends on the speed of the PC.

ANALOGUE BUFFER

The circuit diagram in Fig.5 is for the simple analogue signal pre-conditioning "front-end" that is used prior to the sampling circuit. It comprises a single op.amp buffer, IC1a, which has two levels of gain, set by switch S1 between ×1 and ×10. Switch S2 allows the signal to be a.c. or d.c. coupled, although in most instances only a.c. coupling will find significant use. The post-processed signal is output to the ADC's input (IC4, pin 8 in Fig.6) as a d.c. level.

Using a TL082 op.amp, as shown, the maximum output signal level obtainable is 3V peak-to-peak, after which clipping occurs. Other op.amps having rail-to-rail output swings could be used instead. The input to ADC pin 8 must always lie in the range 0V to +5V. DO NOT attempt to feed external signals that are outside this range directly into the ADC input. Note that the "scope" display in the upper area of the screen is also limited to about 3V pk-pk maximum.

In a quiescent (no signal) a.c. state, the d.c. output level is approximately 2·5V, as set by the potential divider formed by resistors R5 and R6, and smoothed by capacitor C6.

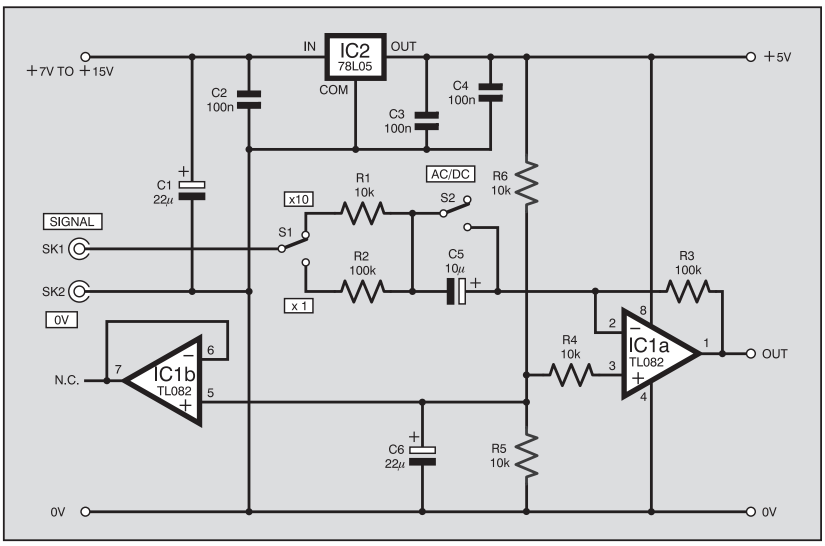


Fig.5. Circuit diagram for analogue signal pre-conditioning "front-end".

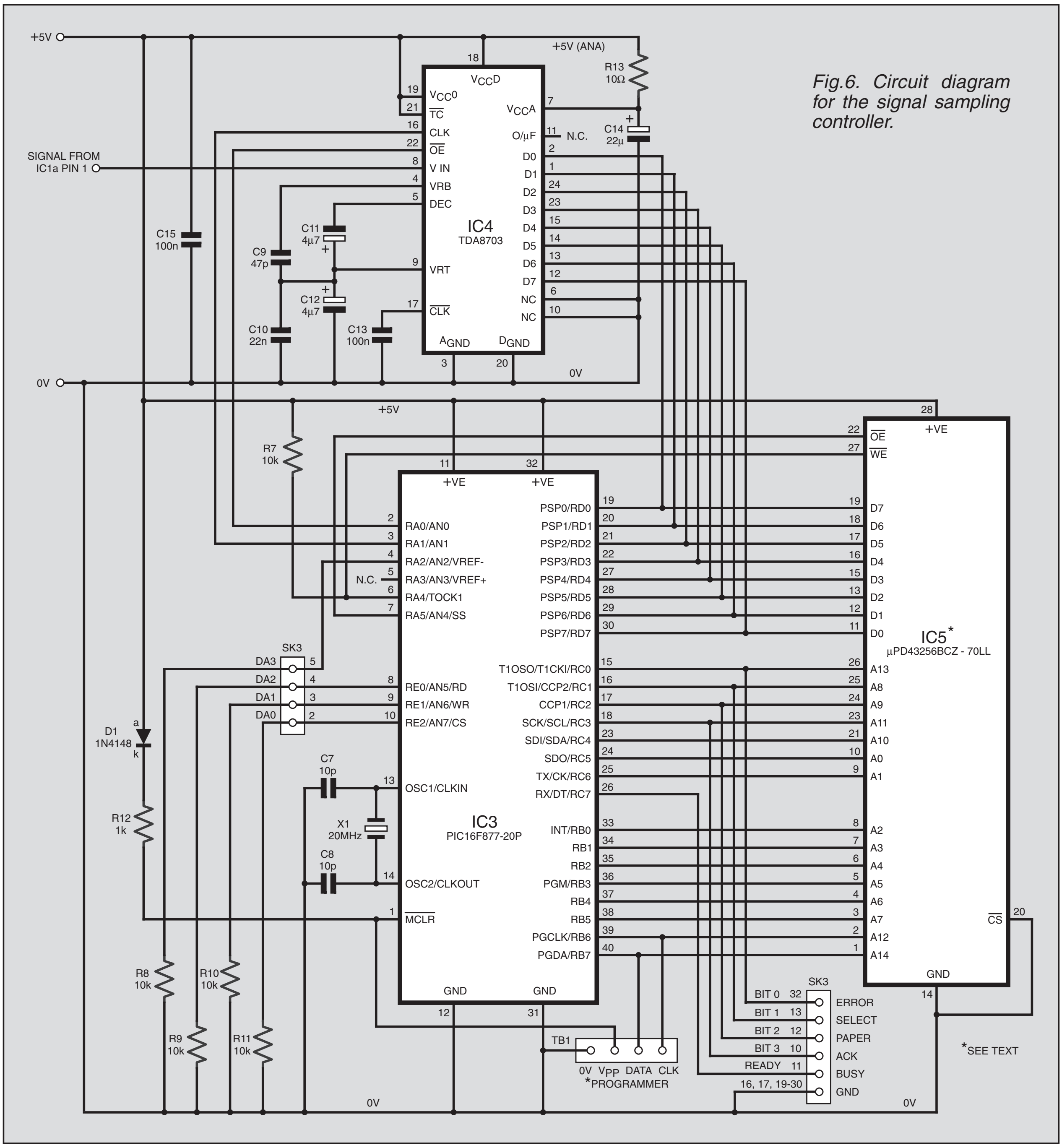


Fig.6. Circuit diagram for the signal sampling controller.

SAMPLING CIRCUIT

The circuit diagram for the signal sampling controller section is shown in Fig.6. The PIC16F877-20 microcontroller, notated as IC3 and running at 20MHz, is in charge of the process. Its first task is to control the analogue-to-digital converter (ADC) IC4. The PIC's own internal ADC is not fast enough for use with this design.

The external ADC receives analogue audio signals at its Vin pin. The PIC repeatedly sends conversion pulses from its RA1 pin to IC4's CLK pin. The effective sampling rate is approximately 100kHz.

Shortly after each CLK pulse, allowing a suitable conversion time to suit the 40MHz ADC, the PIC sets the ADC's output enable pin ($\overline{\text{OE}}$) low. In response, the ADC presents the converted data in 8-bit binary format to its D0-D7 outputs. These outputs connect to the D0-D7 inputs of the 32 kilobyte SRAM (static random access memory), IC5.

The memory's read/write input/output function pins $\overline{\text{WR}}$ and $\overline{\text{OE}}$ are controlled by PIC pins RA4 and RA5. RA4 is biased via resistor R7 to the +5V line as it has an open-collector output.

To latch data into the memory, $\overline{\text{WR}}$ is taken low while $\overline{\text{OE}}$ remains high. The PIC then increments an internal 2-byte counter and outputs its value via Port B and Port C to the memory's address pins A0-A14. The memory is now ready to accept the next data byte at this updated address.

When the counter has reached its maximum and Port C pin RC7 goes high, the system now goes into readback mode in which the ADC is inhibited and data is output from the memory back to the PIC and then to the PC, via parallel printer port connector SK3.

Via its BUSY line connection, the PC responds to RC7 and starts issuing data retrieval commands, via its DA0 to DA3 data lines, to the PIC. In response, the PIC steps the memory through each of its addresses, retrieving bytes as it does so.

Each byte is output as two nibbles (four bits) to the PC via lines RC0-RC3 and the PC's "handshake" lines Error, Select, Paper and Ack (full credit to Robert Penfold for introducing us all some years ago to using the "handshake" lines).

On receipt of each data byte, the PC stores it and signals to the PIC to send the next byte. This continues until all bytes have been transferred. The process then starts again.

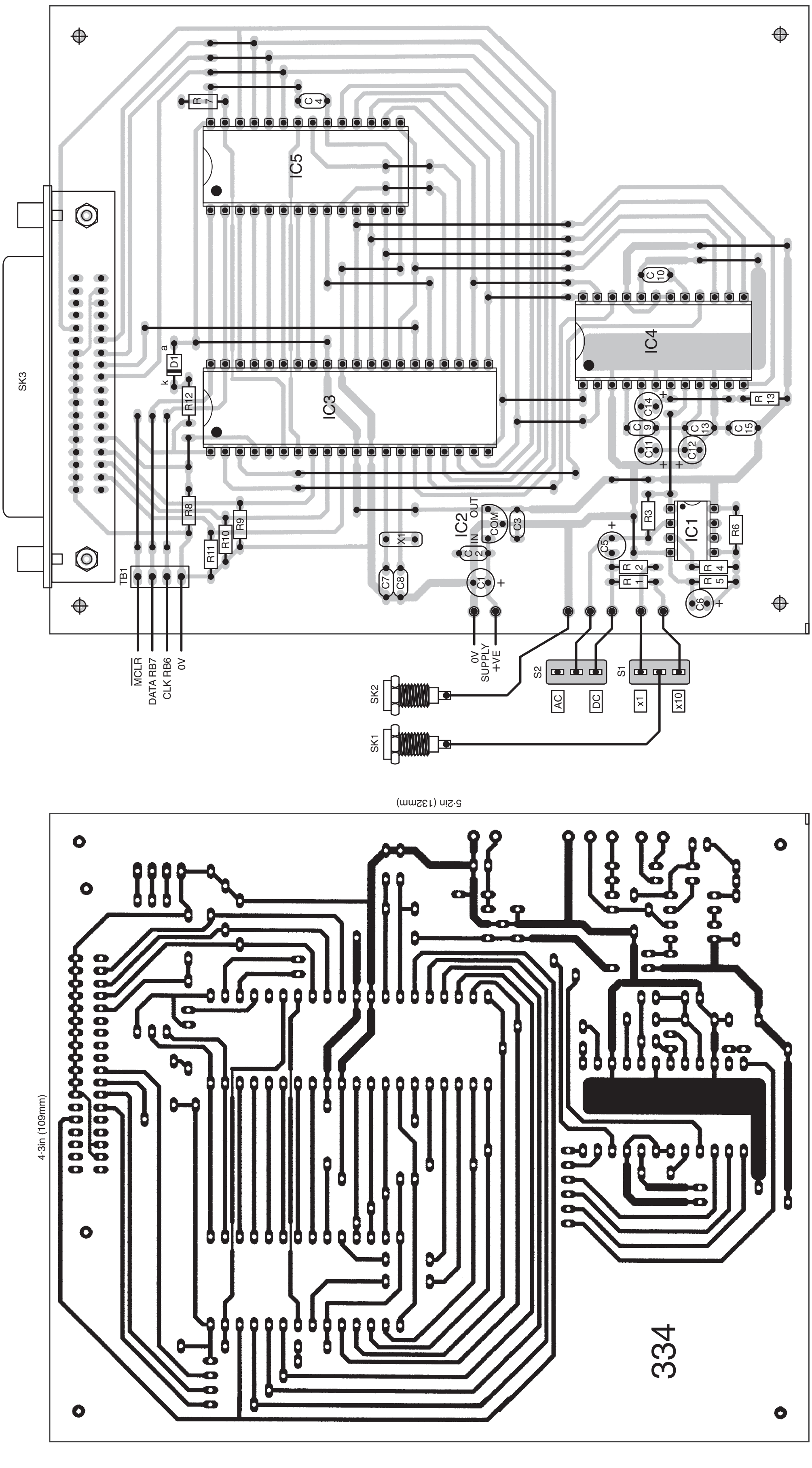


Fig.7. Component layout and full-size underside copper foil master track pattern for the PIC Spectrum Analyser.

POWER SUPPLY

It is intended that the unit should be powered from a d.c. source between about 7V and 15V, preferably from a bench power supply, although a 9V battery could be used for a short period. IC2 (Fig.5) regulates the d.c. source down to +5V, as suits the digital circuitry (**do not exceed 5V**).

Current consumption of the complete unit is quite heavy, at around 73mA.

CONSTRUCTION

Component and track layout details for the printed circuit board (p.c.b.) are shown in Fig.7. This board if available from the *EPE PCB Service*, code 334.

Insert and solder the inter-track links first, using 24s.w.g. enamelled copper wire. It does not need to be insulated if you ensure that the links are moderately straight and not in danger of touching each other.

Use sockets for the d.i.l. (dual-in-line) i.c.s, but do not insert these i.c.s until the correctness of the power supply has been fully checked. Regulator IC2 must be inserted, though. Insert and solder the other components in order of size.

Check the soundness of your assembly, including the adequacy of the soldering and the correct polarity of components as appropriate.

Connect the board to a suitable d.c. power supply and ascertain that +5V exists at strategic points around the board, referring to the circuit diagrams as necessary.

When satisfied, power down and insert the remaining i.c.s. If the PIC has not yet been programmed, you can do so now via *PIC Toolkits MK2* or *Mk3 (TK3)* (July '98 and Oct/Nov '01 respectively) and pin-header TB1. This has its pins in the author's standard order. (Alternatively, you can buy a preprogrammed PIC – see *Shop Talk*.) Referring back to Fig.6, it will be seen that resistor R12 and diode D1 permit the correct use of the PIC's $\overline{\text{MCLR}}$ pin 4, both during and after programming.

A case is not used with the prototype and the choice of a suitable one if required is left to the constructor. The author connected the switches using short lengths of 18 s.w.g. enamelled copper wire.

SOFTWARE SOURCE

Software for this design is available for free download from the *EPE* ftp site, or on 3.5 inch disk (for which a nominal handling charge applies) from the *EPE* Editorial office. See the *EPE PCB Service* page for more details.

The PIC program is supplied in three file formats, the source code (ASM written in TASM), HEX code (MPASM) and OBJ code (TASM).

Software for the PC has been written in Visual Basic 6 (VB6) and is supplied as an "executable" (EXE) file that ideally requires VB6 to be already installed. However, if you do not have VB6, you need to also copy in the contents of the "VBRunTime" folder as well.

Create a folder called SPECTRUM (or any name of your choice) and unzip all files into it, (including the above VB files if necessary) using a facility such as WINZIP (available for free download from **www.winzip.com**).

Ensure that you use a recent edition of WINZIP otherwise filenames might become corrupted, causing a system crash. Older versions of some unzip facilities truncate file names to eight characters plus extension. Some file names for this design are much longer.

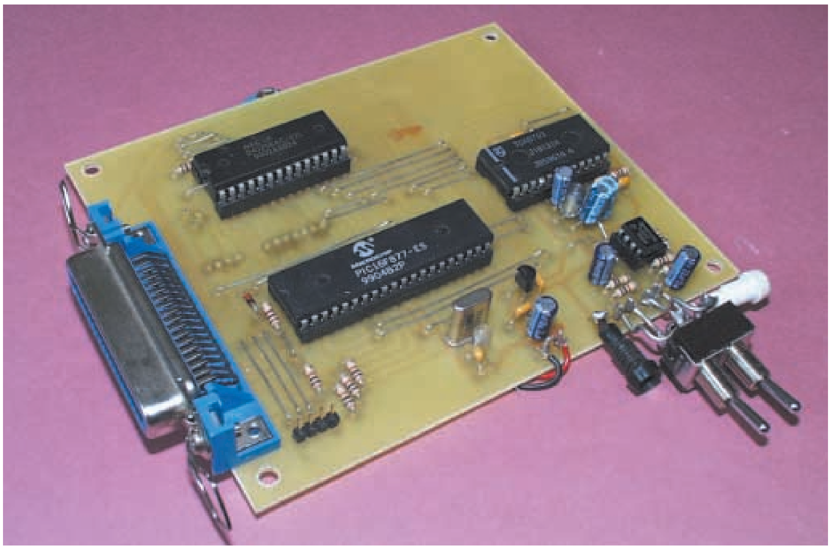
Readers familiar with VB6 will recognise that various VB6 source code files are included with the software. Other files are included that are for demonstration purposes from within the program.

PC INTERFACING

Connect the PC's parallel printer port via a standard Centronics printer cable to the p.c.b. and switch on power.

From within the SPECTRUM folder, double-click on the SPECTRUM icon to launch the program. (The full name of the icon, which might not be shown by your PC, is SPECTRUM.EXE.) You should be greeted by a screen similar to that shown earlier in Fig.1, but without any waveforms, of course!

This is the "front page" through which the primary data analysis is done. There are other options discussed in a moment. The program has been written for use with an 800 × 600 format screen. There will be a slight cut-off at the righthand side of the screen for users only having a 640 × 480 format, but all the essential click-options are visible.



COMPONENTS

See SHOP TALK page

Resistors

R1, R4 to R8, R10, R11	10k (8 off)
R2, R3, R9	100k (3 off)
R12	1k
R13	100Ω

Capacitors

C1, C6, C14	22µ radial elect. 16V (3 off)
C2 to C4, C13	100n ceramic, 5mm pitch (4 off)
C5	10µ radial elect. 16V
C7, C8	10p ceramic, 5mm pitch (2 off)
C9	47p ceramic, 5mm pitch
C10	22n ceramic, 5mm pitch
C11, C12	4µ7 radial elect. 16V (2 off)

Semiconductors

D1	1N4148 signal diode
IC1	TL082 dual FET op.amp (see text)
IC2	78L05 +5V 100mA voltage regulator
IC3	PIC16F877-20P microcontroller, preprogrammed (see text)
IC4	TDA8703 analogue-to-digital converter
IC5	µPD43256BCZ-70LL 32KB SRAM

Miscellaneous

S1, S2	min. s.p.d.t. toggle switch (2 off)
SK1, SK2	input signal connector(s) to suit application. e.g. 2 x 2mm sockets)
SK3	Centronics 36-way female connector, right-angled p.c.b. mounting
X1	20MHz crystal

Printed circuit board, available from the *EPE PCB Service*, code 334; case to suit (see text); p.c.b. supports (4 off); 8-pin d.i.l. socket; 28-pin d.i.l. socket; 22-pin d.i.l. socket; 40-pin d.i.l. socket; 4-pin 1mm pinheader (see text); 1mm double-sided terminal pins; linking wire (see text); solder, etc.

Approx. Cost Guidance Only **£39** ***excl. case***

DIRECTORY ACCESS

Some prerecorded and simulation waveforms have been included with the software, and it is worthwhile familiarising yourself with what spectrum analysis displays look like in action before you run the hardware.

The files available can be listed by clicking on the green ALL button at the bottom righthand side of the screen (see Fig.8). This calls up the directory (folder) sub-window which displays all files held in the Spectrum folder. Click the button now to reveal the display (see Fig.9). The files shown in Fig.9 are the author's and not included with the software.

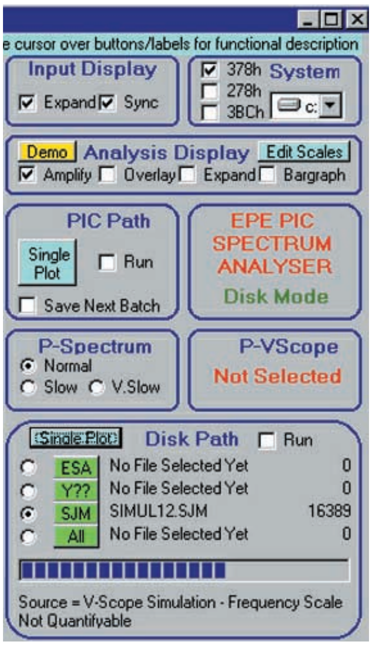


Fig.8. Control panels of the Spectrum Analyser main PC screen.

This directory facility is a cut down version of that used in the author's *PIC Toolkit TK3* software (Nov '01) and has many useful facilities included. It is too lengthy to discuss here, but notes about it can be viewed by clicking on its blue NOTES button. In a nutshell, though, double-clicking on any file name loads it into the Spectrum's allocated memory area.

Although all files having any extension are accessible by the ALL route, in practice you will normally only require files having the following extensions:

- ESA – waveform data recorded through the PIC Spectrum Analyser and its own software.
- Y?? – waveform data recorded by the author's previously mentioned *P-VScope*, where ?? represents the year number.
- SJM – simulation files created by his original *EPE Virtual Scope* (Jan/Feb '98)

The other green directory buttons have these extensions labelled on them (see Fig.8). This allows you to be selective in which of the three main file groups you wish to search for a file.

Folder paths may be accessed in the usual Windows fashion by means of the lefthand sub-window of Fig.9.

Double-click on one of the file names having an SJM extension. This loads the file and returns you to the main screen.

Having selected and input a file, its name is shown alongside the button through which you accessed it. Until a file is loaded, other buttons will show No File Selected alongside.

On an 800 × 600 screen the file sizes will also be seen to the right. This is for information only and has no practical purpose.

SIMULATION EXAMPLE

To the left of the green buttons are four small circular "radio" buttons. On clicking them a black dot appears at their centre. This causes the named file to be run through the analysis routine. If no file has been selected yet, you will be reminded by a sub-screen message.

Processing of a sectional block of file data commences immediately the radio button is clicked. The data is interpreted as a waveform in the screen's upper "scope" window. It will be seen to be "refreshed" at regular intervals. At each refresh the next block of file data is processed, until the file end has been reached, whereupon it recommences from the start.

Each data block's processing results are displayed as spectral analysis peaks in the lower "scope" window. With waveforms having SJM and Y?? extensions, the analysis is not related to any frequency scales, because the files do not hold such information that the software can use.

Files having an ESA extension, however, which are recorded by the PIC Spectrum Analyser *do* have associated frequency scale markings. These are shown below the analysis window (but hidden with other extensions), see Fig.1.

The Single Plot and Run options in the Disk Path zone allow you to single-step through waveform blocks, or run them continuously. A blue bargraph displays how far through the file data you have progressed.

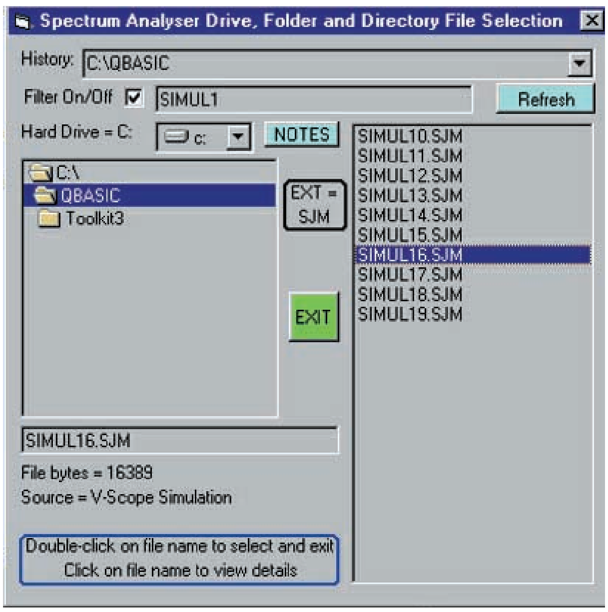


Fig.9. Folder and directory selection sub-screen.

LIVE ANALYSIS

When you have viewed the analysis displays for several different files, turn your attention back to your completed board assembly.

Connect a signal generator into its input and set the signal amplitude output for somewhere between about 1V and 3V peak-to-peak, with the op.amp's gain switch S1 set to ×1 and the coupling switch S2 to a.c.

Above the Disk Path zone are two other zones, marked P-Spectrum and P-VScope respectively. The latter should be empty of control options, with the message Not Selected shown, but the P-Spectrum zone should have three radio buttons visible (the default option when the program is first run).

The "Normal" button should be seen to be active, having a dot at its centre. The three buttons control the rate at which the hardware samples its data (Normal, Slow, V.Slow). Slow is ten times slower than Normal, and V.Slow is ten times slower than Slow. Slowing down the sampling rates allows lower-frequency signals to be sampled to give greater detail.

PRELIMINARY HARDWARE CHECK

If you click between the three buttons now, the software will do a preliminary check that your cable is plugged in and the power switched on. If either situation is untrue an Error message will displayed telling you so.

Which brings us to setting the correct Port register used by your PC to access its printer port. There are three options likely, addresses 378h (hex), 278h and 38Ch. It is probable that your PC will be set for 378h, but not necessarily so.

If you see the said Error message, first double check that the power is on and the cable connected. Click the OK button and try again.

If the message appears again, and assuming that your assembly is satisfactory, try a different Port address. In the System zone at the top right of the screen, the three register addresses have dedicated option buttons. Button 378h will currently have a tick mark. Click on 278h to try that register. The previous message will reappear if it is not correct, in which case try 38Ch.

If still no joy, you are likely to have made an error in your board construction. Recheck it all and try everything again.

Assuming your board is OK and you have found the correct register (signified by the message not being shown), leave it selected. The information is stored to disk and will be recalled next time you load the program.

HARDWARE RUNNING

Refer now to the PIC Path zone above the P-Spectrum zone. This allows you to select live analysis as a continuous process, or to single-step between live plots when you wish. Click on Continuous.

The system should now input waveform data from the board and analyse its content in the same way it did for your simulation tests.

Clicking Single Plot will stop continuous running and do as the button says. To step between plots press any keyboard key, or click the button again.

To sample data and record it to disk for future recall, click the Save Next Sample tick-box. A 2K block of live data will be stored at the end of the next batch. It is

filed with a unique date and time related name which is decoded when highlighting file names in the directory option and when a file has been selected. In the latter case, the information is displayed at the bottom of the Disk Path zone.

INPUT WAVEFORM DISPLAY

The Input Display zone allows you to select how the input waveform is displayed in the upper "scope" zone. This is purely for information and has no bearing on the analysis. You have currently been viewing it in its default style.

Clicking on Expand widens the screen width distance between plotting points, drawing a line between them. This enables a better view to be seen when input waveform cycles are closely spaced. It does not affect the actual sample rate – it is purely cosmetic. The scale values do not change so you must mentally divide them by ten in this mode. Clicking again on Expand returns you to normal input display mode.

The Sync button cause the start of the waveform at the left of the screen to occur at similar positions in its amplitude. The triggering point cannot be changed – it occurs on the upwards slope, at somewhat over the midway voltage level (as seen by the ADC). Clicking Sync again turns it off.

ANALYSIS DISPLAY

There are several options available through the Analysis Display zone.

The Amplify button amplifies the height of the analysis waveforms so that lower amplitude peaks can be more readily viewed (compare Fig.3 with Fig.4).

The Expand button is similar in action to the Expand button for the Input Display. It allows you to view the low frequency left-hand side of the analysis graph in "close-up". It effectively expands the display by 10 times, with the high frequency end not shown (see Fig.10).

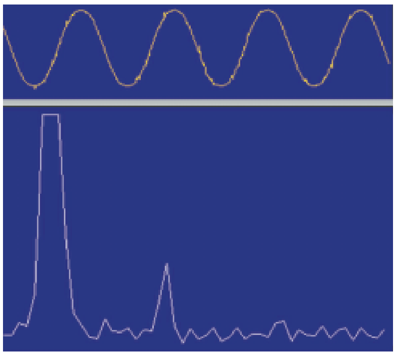


Fig.10. Analysis screen in Expand mode.

The Overlay button causes successive analysis data to be superimposed on the previous batches, allowing a complex display to be built up over time. This is useful when sampling signals whose content is constantly changing and you wish to know which frequency bands prevail most strongly (see Fig.11).

Clicking Bargraph displays the analysis peaks as individual vertical lines, allowing frequency differences to be more readily seen (see Fig.12).

All four option buttons work on an on/off alternating cycle.

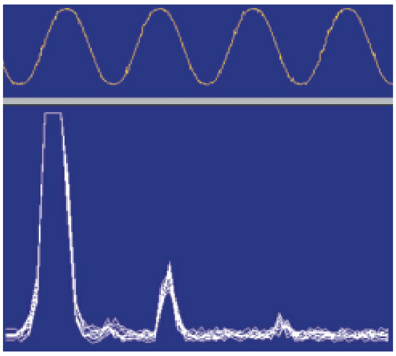


Fig.11. Analysis screen in Expand mode with overlay active.

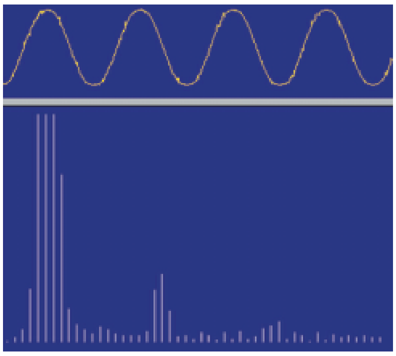


Fig.12. Analysis screen Expand and Bargraph modes active.

EDIT SCALES

When in live sampling or ESA playback modes, frequency scales are shown below the analysis window. The actual values shown are those set for the prototype unit. Individual units may exhibit slightly different sample timings, due to normal variations in the exact frequency generated by the crystal. Consequently, the scales can be edited to suit.

Click on the Edit Scales button. Both scale markings will now be displayed with a white background rather than the usual grey. A yellow Save Scales button is also revealed (see Fig.13). Click the mouse cursor on the scale strip you wish to amend. The scale is now in "text" mode and information can be entered into it by any of the usual keyboard keys.

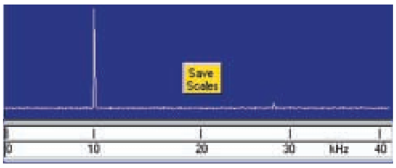


Fig.13. Typical scale editing display.

In the upper scale, graduation lines are shown. These may be pulled back by using the Delete key, or pushed forward by the space bar. This allows you to feed the unit with a signal (preferably a sinewave) of known frequency, from a signal generator, and the scale graduations can then be shifted if necessary to match the known frequency.

Similarly, click on the numeric scale and the values there can be shifted as required, and their values amended. Additional graduations and values can be entered if you want.

When satisfied, click on the Save Scales button in order to save the new data to disk. A confirmation message will then appear, "Scales saved OK". The revised scales will be recalled next time you run the program.

Note that there are five sets of scales available. The program automatically selects the correct scale for the hardware mode. Three are specifically for use when the PIC Spectrum hardware is used, with a pair for each sampling rate available.

If you use the *P-VScope* hardware, selecting it by clicking in the P-VScope zone, the other two pairs are used, again depending on the sampling rate chosen. All pairs can be independently amended and similarly saved to disk.

The *P-VScope* is a dual-channel design, and the Channel button included in its zone clicks between the channels. Should you wish to return to using the PIC Spectrum hardware, click on its zone, an action which then hides the *P-VScope* zone buttons again. Information on which hardware zone is currently being used is stored to disk for future recall.

POP-DOWN NOTES

All screen buttons and most captions have messages "behind" them which are activated when the mouse cursor is hovered over them. These give brief details of the functions performed via the associated screen areas. Moving the cursor away from the message hides it again.

The message options cannot be switched off, nor does VB6 appear to allow them to become hidden after a given time, unlike some programs the author has used. If the messages get in the way, move the cursor well away from active zones (to outside the main screen area, for instance).

DRIVE BUTTON

At the top right of the screen in the System zone is a Drive button. This allows you to tell the program which drive letter should be regarded as your hard drive. The options offered depend on the drives installed or partitioned on your machine. Do not select a drive into which you insert floppy disks or CD-ROMs.

The effectiveness of this option is not known since none of the author's machines have a partitioned drive. It seems to be a facility that could be useful, however. Reader feedback on this would be welcomed at *EPE* HQ.

PROGRAM EXIT

Two options for exiting the program are available. The most obvious is via the standard Windows X button at top right. Not so obvious is the option to click on the zone words EPE PIC SPECTRUM ANALYSER, which has the same effect. Either path may be used.

DEMOS

At the heart of the VB6 spectrum analysis software is a short mathematically-based routine. This is a variant of a routine given in a three-part article, written by the late Paul Cuthbertson, for *EPE*'s sister publication the *Modern Electronics Manual* (appearing in quarterly Supplements 61 to 63). Part one was on the theory of spectral analysis. Parts two and three included various software examples

and an elementary hardware construction design.

Experimenting with the software, the author was so impressed by its apparent capabilities, it became the inspiration for this PIC controlled design.

The principle behind the analysis routine is too mathematical for the author to understand or describe. However, for the sake of those who might like to ponder how the analysis is achieved, the original *MEM* routine is supplied on disk with the other software for this PIC-based design.

Additionally, a demo program has been prepared and which can be accessed via the yellow Demo button in the Analysis Display zone. It needs waveform data to have already been loaded into the program before it can be run. This may be done via the Disk Path buttons, or directly through the hardware.

DEMO PANELS

With waveform data loaded, click on Demo to display another sub-window. This contains four display panels (see Fig.14).

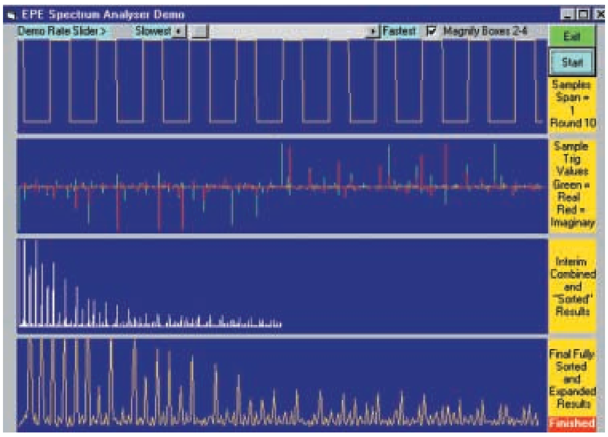


Fig.14. Analysis process demonstration screen example.

The top one shows the basic waveform. On clicking the blue Start button, the first stage of analysis begins. Pairs of waveform values are sampled at successive intervals along the length of the full sample batch of 1024. The screen displays each span-line superimposed on the basic waveform, illustrating the points between which the sample values are being taken.

On the first round, the span between points is half the total number of samples (512). An example taken at an early stage when sampling a sinewave is shown in Fig.15. The analysis relates the difference between the sample values to specific (pre-calculated) sine and cosine values. Each result is stored in sequence.

Sampling at this span interval commences at sample 1 and proceeds for 512 samples. Round 2 then commences, again from sample 1, but this time the span is half the previous (256) and two pairs of samples are taken, the second pair commencing 256 places after sample 1. The process proceeds through 10 rounds, each round the span being halved and the sample pairs doubled. Fig.16 shows an example during the third round.

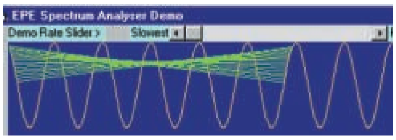


Fig.15. Example of the sample spans in the first stage of analysis.

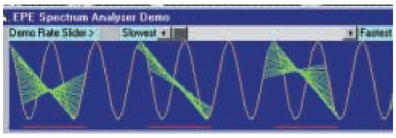


Fig.16. Example of the sample spans in the third analysis stage.

SINE VALUES

The second panel shows the calculated sine/cosine values being stored in position as they occur. Fig.17 shows an example taken during the fourth round when sampling a square wave.

Paul Cuthbertson stated that some values are regarded as "Real" and others as "Imaginary", for reasons not understood. They are displayed in different colours. During analysis, the Real and Imaginary samples are combined in relation to their span positions, so reducing the number of calculated samples, while increasing the values of those retained.

The sample positions retained are directly related to equivalent frequency spectrum values, the higher the value, so the greater detected dominance of the equivalent frequency. Panel 2 (in normal mode) shows all sample position values as they occur.

There is a "magnify" mode in which only the retained values are shown in each round, and the sample values are also increased according to which round is being processed, to make the value differences more apparent. An example taken in round 6 for the square wave is shown in Fig.18.

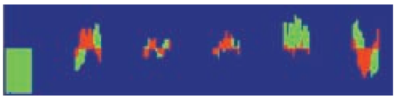


Fig.17. Example of sine/cosine values display during analysis of a square wave, round 4.

The third panel shows the "retained" analysis values, but "sorted" into their final frequency-related positions, which are determined according to a complex mathematical procedure. Fig.19 shows panel 3 at the same point in time as panel 2.

The mathematics are not understood by the author, but he analysed the relationship between the original and "sorted" positions and created a look-up table that is used to position the values in panel 3. The table is held in software file SpectrumTable.txt and may be examined via a text editor.

WELL SORTED

The final panel shows the graph of the final sorted spectral analysis values (refer back to Fig.14).

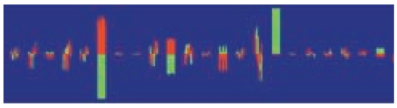


Fig.18. Example of panel 2 in round 6 for a square wave.

Fig.19. Panel 3 at the same point in time as Fig.18.

The demo window has various control buttons. The rate at which the demo progresses is controllable via a "slider" at the top. At its slowest rate, you can study each step of the process. The fastest rate illustrates the overall process more clearly as it progresses from round to round.

The values generated in panels 2 to 4 can be "magnified" via the top-right tick-box, allowing the differences between values to be more readily appreciated (as was done for Figs.14 to 20).

The demo may be restarted from the beginning at any time by clicking on the Start button. Apart from being informative, the demo can also produce some interesting patterns (three of which are shown in Fig.20).

Variants of the preceding paragraphs can be viewed by clicking the four yellow zones at the right of the demo screen.

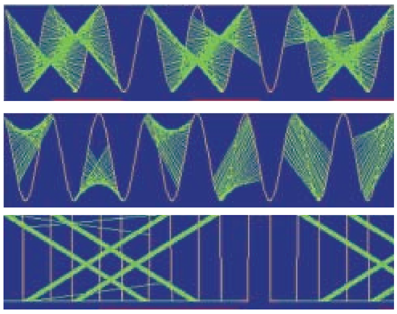


Fig.20. Three examples of "interesting" analysis patterns.

Buttons and text labels have underlying "messages" when the mouse is hovered over them. A return to the main screen can be made by clicking on Exit or the Windows X button.

Paul's original QBasic routines (written for his own hardware) can be read as a text file, SpectrumMEM.txt, which accompanies this program. It has its own explanatory comments.

FURTHER READING

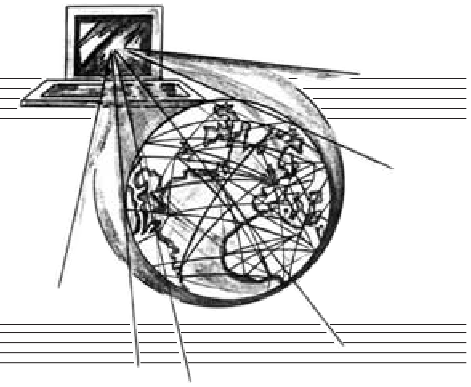
Modern Electronics Manual, Supplement 61. Paul Cuthbertson. Wimborne Publishing Ltd.

Charles Lepple describes FFT in simple terms and provides further links through his web site:

www.foo.tho.org//charles/fft.html.

The Fastest Fourier Transform in the West is at **www.fftw.org**. This site has its own FFT software and many links to other sites, plus a list of further reading, etc.

Note that Figs. 10 to 20 have been "reversed-out" (black on grey) for clarity when printed.



NET WORK

ALAN WINSTANLEY

Happy Shopping

IN RECENT columns I examined a number of shopping cart systems available to Internet users wishing to purchase electronic components online. The site of RS Components (**rswww.com**) stands out as a model of excellence, but it is unfair to compare this class-leading effort against the more modest web sites of those suppliers whose budgets for conducting e-commerce are more restricted.

One fundamental problem is that RS will charge postage for non-account holders, which can render the placing of small orders uneconomical, so it's best to plan ahead and group orders together, or shop around: after all, the pages of *EPE* contain dozens of adverts from small, hardworking suppliers all of whom offer personal service and are eager to do business with you readers! Companies such as Magenta Electronics (**www.magenta2000.co.uk**) offer pre-programmed PIC chips for nearly all *EPE* projects, and ESR (**www.esr.co.uk**) are eager to help you with discrete components and semiconductors.

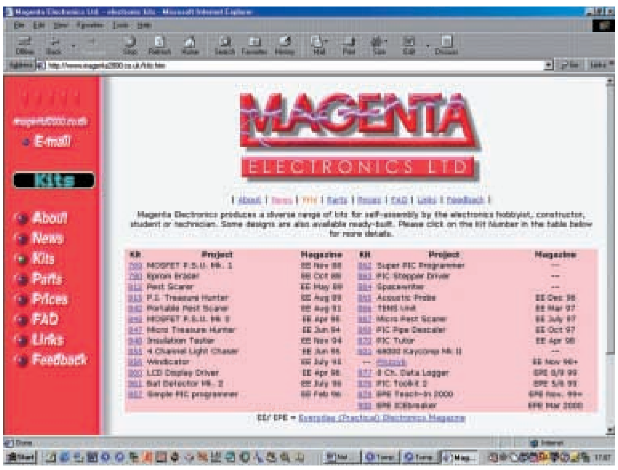
Readers will recall from last month that I highlighted problems with the site of RS Components' competitor Farnell (**www.farnell.com**), whose web site has in my view an unintuitive user interface. By comparison, their arch rival RS has stolen a very clear lead, and I can't help feeling that if Farnell's site had warned that my online order had not yet been placed, as RS Components' site does in big red letters, then my order would have been submitted successfully. Instead I had to phone it through.

It is sometimes less time-consuming and easier on the phone bill to try to prepare an order when offline, which can involve thumbing through catalogues or shopping lists and then jotting down part numbers. Occasionally I flick through a catalogue at leisure, tapping the part numbers into my Handspring Visor which I eventually upload to my PC. From there, part numbers can be pasted into a supplier's order form or email when I next go online.

However, a powerful online shopping cart system can make life far easier if it has a good search facility that enables part numbers to be tracked down by manufacturer or product name. The Internet was made for complex product searches as **Amazon.com**'s web site demonstrates.

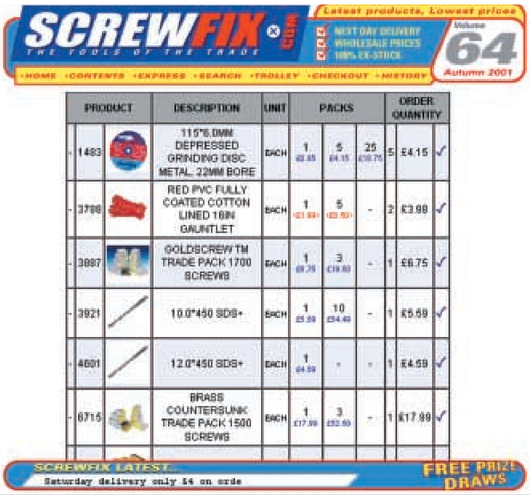
Screws Fixed Online

What has proved to be the fastest and easiest shopping cart system I have ever used, belongs to the online hardware mail-order company Screwfix Direct (**www.screwfix.com**). Their "Express Order" system really does work fast. By preparing a list of order numbers beforehand – for which you need the paper catalogue of course – it is easy to tap them into their Express Order form.



Results were returned instantaneously along with a small image of the products. This over a 56k dial-up connection! Needless to say, my workshop is now bulging with boxes of screws, fasteners, grinding discs and drill bits all delivered promptly by Screwfix.

The point is this: the easier a supplier's web presence makes it for users to place an order online, the more likely they are to develop the habit of placing routine orders. If customers suffer any problems or dissatisfaction, it is likely to lose the supplier business and customers will go elsewhere. This will only ever become more apparent as Internet access continues to become more accessible. It's a cruel world but you have to please the customer if you want to keep them.



The DTI's UK Online for Business scheme, with which I am involved, is spending millions on TV and press advertising with the intention of encouraging industries to adopt Internet services and grab a piece of the action for themselves. In fact things have moved on from promoting the adoption of a mere "me too" static web site; that's old hat and companies are now being encouraged to go to the next level, e.g. integrating their stock records and accounting systems into an online strategy.

This could offer the potential of a sophisticated and complete end-to-end customer-facing ordering system. This is expensive technology to implement which is beyond the reach of many small companies. The implementation of the Euro currency in many EU member states is also a complication for exporters.

One problem we have in the UK, of course, is the failure to roll out broadband Internet services (i.e. cable, ADSL) quickly and cheaply enough, coupled with the complexities and the relatively high running costs of Internet access. These costs make many people think twice before going online, it inhibits the uptake of Internet usage and costs UK companies lost business.

It is said that Internet usage in the UK has recently levelled off for the first time. Perhaps the novelty has worn off and dial-up access is just too tiresome and slow. Home computers don't always come as second nature to the vast proportion of the population either; they depreciate very heavily and judging by what I overhear in out-of-town electrical stores, good practical and reliable advice for beginners is thin on the ground.

Thanks to the strangulation of Internet access and the fall-out amongst ISPs persevering in a difficult market, there is still a long way to go before we are ordering pizzas by Internet, as they have routinely done in the USA for several years.

You can contact the writer at **alan@epemag.co.uk**.

Special Feature

RUSSIAN SPACE SHUTTLE REVISITED

BARRY FOX

Buran – the Russian space shuttle – was mothballed after its only flight in 1988. Now there is talk of it flying again.

WHEN I first travelled to Moscow, a few years ago, to see Proton space rockets being mass-produced for satellite launches at the Baikonur Cosmodrome in Khazakstan, there was passing talk of Buran, Russia's answer to NASA's space shuttle. At Baikonur we were told that Buran had been mothballed after its one successful test flight, and there was no chance of it ever flying again, and nothing to see.

SPACE TOURISM

Since then work on the International Space Station has begun in orbit, with demand growing for larger cargo payloads in the NASA shuttle. Russia has discovered space tourism as way of making money, taking $20m from rich American Dennis Tito when the Americans refused to take him up to the ISS. The satellite launch program, using Protons, has recovered from embarrassing failures and is raking in around $100m a shot.

By the time I went back to Baikonur in June 2001, for another Proton launch (*Astra 2C*), there was talk of taking Buran out of mothballs. Perhaps stung by the sceptical reaction to this by Western aerospace engineers and press, the Russians decided at the last minute to throw open the vast hanger complex in the Steppes desert, where Buran still sits where she was assembled on rail tracks to the launch pad more than ten years ago. The Western visitors were given a tour of the hanger – even encouraged to climb onto the rocket launcher to see for themselves that the Buran beast is real, and is not the rusting pile of junk some people have been curiously anxious to insist it must be.

RUBBISHING

When I came back and reported that aerospace engineers in Russia think the world is at last ready for Buran's sledgehammer approach to rocket launching, some people were excited while others have gone out of their way to rubbish the idea. Reaction to news of the Russian's gung ho plans has brought a mixed reaction. Some of the rubbishing clearly stems from the intense rivalry between Russian space companies Khrunichev, who make Proton satellite launchers, Khrunichev's Western partners and Energya who built the launcher for Buran, but makes only the top, fourth, stage of the Proton and will soon be squeezed out by a Khrunichev re-design,

"The best space news in years...perhaps it will kickstart the other aerospace companies who seem to have no ambition to move forward in rocket design in anything other than baby steps" says a Western aerospace engineer. "A joke" says the Head of Marketing in Russia's Molniya. "Scrap metal" says a Russian Web site.

The Russian spokesman was not speaking on behalf of the Russian government, says International Launch Services, the American company which works with Khrunichev on Proton launches.

But who in the West – or the East for that matter – really knows what the Russian government is thinking?

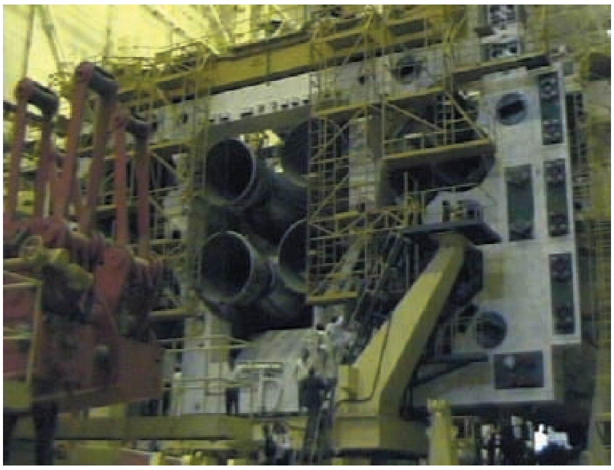
Here is what I saw and heard. Form your own opinion, perhaps bearing in mind that ten years ago anyone suggesting Russia would soon start earning dollar currency by launching Western satellites from a hitherto secret military base on converted intercontinental ballistic missiles would have been laughed off as a fool. Check out the Russian web site, too (**www.buran.ru**).

ONE FLIGHT

Buran (Snowstorm/Blizzard) only made one flight, in 1988. The shuttle, which looks like a large utility version of the US design, was un-manned and landed successfully after twice orbiting the Earth. Russia had by then built two shuttles, and three Energya

Buran, the mothballed Russian shuttle, sits on top of the Energya launcher.

The main fuel tank for Buran's Energya launch vehicle.



The main engine thrusters that lifted Buran into orbit.

The launch tower used for space tourism.

launch boosters to carry them. Funding continued because the military saw Buran as vital to any defence system similar to North America's Star Wars. The Russian PR line is that the only component imported was heat resistant paint. And it may very well be so.

In 1990 another Buran orbiter vehicle was built and used for fire tests; it still stands charred in the desert. In 1992 the cash-strapped Russian government cut off funds because Star Wars looked dead and there seemed to be no market for a non-American shuttle.

The Buran project was to have employed 30,000 Russians, with up to 30 launches a year. Some of the old buildings are being renovated to accommodate the Western engineers who now come regulary to Baikonur to launch commericial satellites on Russian Proton rockets.

The landing strip for Buran, called Yubileine ("Anniversary"), was 87 metres wide, and 4500 metres long, with a 500 metre emergency extension at each end. International Launch Services in San Diego recently spent $5 million refurbishing it to land Russia's Antonov cargo-carrier, the only aircraft in the world large enough to fly in satellites from California. Even though Boeing makes these satellites, after buying the Hughes satellite companies, a Boeing Jumbo 747 does not have enough cargo space. (It carries the US Shuttle back to Cape Kennedy, piggyback on top.)

HORIZONTAL ASSEMBLY

Like all Russian space vehicles, and the nuclear missiles on which they were based, Buran and the Energya launcher are assembled horizontally, moved by rail to the launch pad and tilted to vertical. The process takes only a few days. The US system is quite different. Assembly is vertical, in a very tall hanger, and the massive tower is then trundled ever so slowly out to the launch site. The process can take weeks.

All the Buran machinery appears in good working order. The hangers are stacked with spare rocket motor parts and fuel tanks. Not ready to go, of course. But certainly not rusting scrap.

Tip to toe size of the Buran system is similar to the US Shuttle, but construction very different. The Buran orbiter is clad with 40,000 differently shaped ceramic tiles for heat protection. For launch it sits astride the Energya Heavy Lift Booster, with central core and strap-on Zenit boosters round the core – with parachutes and retro rockets for soft landing, recovery and re-use up to ten times.

All the propellants, in the core and side boosters, are liquid – no solid propellant is used. So the system is more controllable. The core fuel tank is 50m tall, and 8m in diamater. The Buran shuttle does not have any rocket engines of its own – so the cargo hold can be large enough to carry loads 17m long, and 4·5m diameter, with four crew and six passengers.

STRAP-ON BOOSTERS

The basic launcher had – and has – four strap-on boosters round the central core, powered by liquid oxygen and hydrogen. An eight-booster version, never tested, was dubbed Vulkan.

Says Leonid Gurushkin, director of launch operations at Baikonur: "There IS a future for this program. Buran is the only system with a 100 tonne payload. By extending the length we can carry 200 tonnes. There is no alternative to Buran and I don't see any coming. Buran can only be flown from here. The huge structures needed to launch it only exist here."

"The launcher is powered by hydrogen, oxygen and kerosene engines" says Gurushkin, assuring it is environmentally friendly. "The strap-on boosters are re-useable. They drop back to the airstrip. In fact only the core unit is lost. The Americans spent billions of dollars getting men to the moon. And what for? To bring back a few kilos of rocks and stones."

Gurushkin believes Buran's time has now come because the International Space Station is creating the need to carry ever larger loads into low orbit. Western launchers carry less than 20 tonnes.

"We have been dreaming of this time" he says.

Although Russia's other state space company, Khrunichev, is a rival to Energya, its director Alexander Kondratiev, says he welcomes any opportunity for Russian space engineers to compete with the West on an equal footing. "Until 1990 we could not tell anyone what we were doing. But now we can show the world our worth."

MUSEUM

Energya has three launch pads at Baikonur and thinks the money to prime Buran's re-birth will come from the West, albeit indirectly. Seventeen Protons have been launched for Western operators in 17 months, and Russia earns over $100m from each. A modern hotel, the Sputnik, has been built in the desert near Baikonur. There is now a museum in a renovated building near the cottages where Yuri Gagarin and most of the other cosmonauts stayed before launch.

The desert home of Sergei Korolev, anonymous chief designer of the Soviet space program, is also now a museum – with "just as it was" books, fridge and furniture. Visitors to the museum get the chance to peer inside the Soyuz capsule where space tourist Denis Tito huddled in foetal position with excreta bags *en route* to Russia's part of the ISS.

And it's all spookily close to some of the 38 missile silos bulldozed at Baikonur under defence treaties. The remains of the sites have been left for all to see

But realistically it's highly unlikely that more than a few dedicated space buffs will make the pilgrimage just to visit the museum. Apart from anything else, Russian bureacracy remains a guaranteed deterrent to all but the most dedicated sightseer.

INCOMPETENCE

I was with the party of Western aerospace experts and executives who recently saw Buran. We arrived on a private flight via Moscow and were three times kept waiting for several hours in near-prison conditions at a transit airport, while too few immigration clerks checked, re-checked and stamped too many papers. At Khazakstan everyone – including the VIPs – were forced to stand for more hours in the scorching midday sun as even fewer immigration clerks X-rayed everything in sight while at the same time checking forms, permits, permits to apply for permits and lists they clearly could not read. The metal detectors were so sensitive that even trouser zips set them off.

Among the sunbaked victims was Len Dest, who heads ILS and pays Russia over $100m a time to launch Proton satellite rockets. At a West-wooing banquet in Moscow, Dest was still so angry he broke all the rules of protocol and gave a speech accusing the host's immigration service of "staggering incompetence".

Desert home for the cosmonauts – now a museum.

The Soyuz capsule used to transport space tourists.

But none of this will bother space tourists like Denis Tito. It might make the two day crouch in Soyuz seem welcome – a bit like progressing from British public school to the real world.

And Leonid Gurushkin says that whatever NASA may say there will most definitely be more tourist space trips from Russia: "We already have many applications. We are currently considering them all and will take whoever pays most. We would like to take a married couple to the space station. We need to continue biological experiments."

Now there's a potential money-spinner from the Western tabloids and a warning that it could be very unwise to discount Russia's chances of ever getting Buran out of the hanger again and up into space. □

SHOP TALK
with David Barrington

PIC Spectrum Analyser

Once again our intrepid Tech Ed has raided his RS spares box to bring us another fascinating PIC-based project. Most of the parts for the *PIC Spectrum Analyser* are, of course, RS types and can be ordered through any *bona-fide* stockists, including many of our advertisers. You can order direct (credit card only) from **RS** on ***01536 444079*** or through the web at ***rswww.com***. A post and packing charge will be incurred.

The μPD43256BCZ-70LL 32-kilobyte SRAM (code 265-465) and the TDA8703 analogue-to-digital converter (code 191-9754) both came from them. They also supplied the 36-way female Centronics connector, right-angled p.c.b. type, code 239-1178.

For those readers unable to program their own PICs, a ready-programmed PIC16F877-20 microcontroller can be obtained from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***) for the inclusive price of £10 each (overseas add £1 p&p). The software is available on a 3·5in. PC-compatible disk (*EPE* Spectrum) from the *EPE* Editorial Office for the sum of £3 each (UK), to cover admin costs (for overseas see page 141). It is also available *Free* from the *EPE* web site:

ftp://ftp.epemag.wimborne.co.uk/pub/PICS/spectrum.

The printed circuit board is available from the *EPE PCB Service*, code 334 (see page 141).

Guitar Practice Amp

Some confusion could arise when purchasing the small p.c.b. mounting 3·5mm stereo jack socket, with two switched break contacts, for the *Guitar Practice Amp* project. Each version looked at appears to have a differing pinout arrangement and the answer may be to "hardwire" the socket to the p.c.b. The one used in the model came from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code JM20W. They also supplied the 6·35mm (¼in.) moulded mono jack socket, with break contacts, for the headphone option, code FJ00A.

The above mentioned company also lists a suitable sub-miniature omni-directional electret mic. insert, code FS3W. Almost any in-line bridge rectifier with a rating of 1A to 2A should be OK for this circuit. The author specifies a KBP204 type and **ESR** (☎ ***0191 251 4363*** or ***www.esr.co.uk***) list two KBP equivalents rated at 2A 50V and 100V, codes 700-250 and 700-251 respectively. They also carry the TDA2030 audio amplifier chip; listed as just the type number.

The printed circuit board is available from the *EPE PCB Service*, code 336 (see page 141).

HT Power Supply

Not too many problems should be encountered when buying parts for the *HT Power Supply*. The stripboard will need to be cut down to size from a regular 2·54mm (0·1in.) matrix piece having 39 holes by 39 copper strips. The two i.c.s and the power Darlington transistor are widely stocked popular devices.

The "step-up" transformer (mains) can be a type rated at 3V-0V-3V at 100mA if output currents of no more than about 2mA or 3mA are required. However, for higher output currents, one having twin 6V 500mA secondary windings is needed. The standard type referred to in the article came from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code WB06G.

The single-pole 12-way rotary switch, with an adjustable end-stop, also came from the above source, code FF73Q. Many suitable alternatives are also available.

Finally, be sure to keep to the minimum or greater working voltages of the output smoothing capacitors and follow the guidelines set out in the article.

Versatile Current Monitor

One or two minor items outlined in the *Versatile Current Monitor* project need considering when ordering parts. But generally speaking, the components should not be too hard to find at your local supplier's shop.

You will probably need to purchase a high voltage metal film or a 2·5W to 3W wirewound type to obtain a "sensing resistor (R1)" of the required low value. Unfortunately, resistors of a small physical size and low power rating in values of less than one ohm appear to be almost impossible to find.

The solid-state, 3V to 24V d.c. 10mA max., buzzer used in the prototype came from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code KU56L. No doubt, most of our component advertisers will be able to offer a suitable equivalent. Some readers may have difficulty in locating the ICL7611 op.amp. The one on the circuit board came from the above company, code AV65V. It is also listed in the latest **ESR** (☎ ***0191 251 4363*** or ***www.esr.co.uk***) catalogue.

The printed circuit board is available from the *EPE PCB Service*, code 335 (see page 141).

Teach-In 2002 – Lab Work 4

Two sources were found for the piezo ceramic "speaker" called-up in the *Rain Sensor* and *Knock Three Times Sensor* circuits, this month's *Lab Work 4 Teach-In 2002* demonstration exercises.

The KPS-100 piezoelectric speaker (disc) is currently listed by **Farnell** (☎ ***0113 263 6311*** or ***www.farnell.com***), code 926-966, and (credit card only) **RS** (☎ ***01536 444079*** or ***rswww.com***), code 172-7289. This is a plain piezo disc, *without* an in-built tone generator.

All the semiconductor devices should be readily available from most of our components advertisers.

PLEASE TAKE NOTE

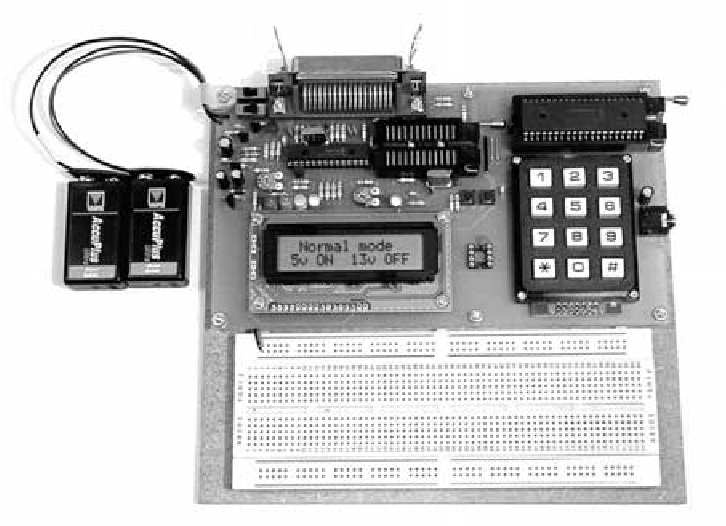
Mains Failure Alarm — *Dec '01*

Page 839, Fig.2. A small supply link wire is missing from point A17 down to B17 on the stripboard component layout. This is, of course, needed to power IC1 at pin 14.

PIC Polywhatsit — *Dec '01*

Page 870, Fig.2. The "ring" of the output socket SK2 should be connected to the 0V rail and not V_{REF}. Wiring diagram Fig.5 is correct.

Learn About Microcontrollers



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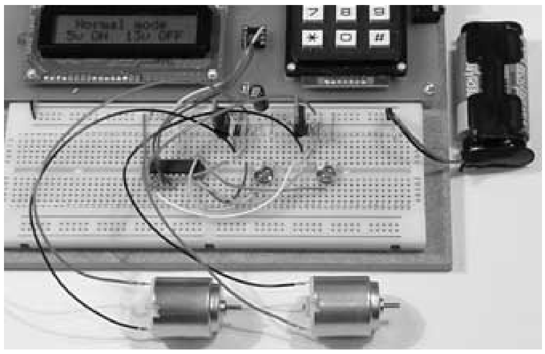

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Constructional Project

VERSATILE CURRENT MONITOR

TERRY DE VAUX-BALBIRNIE

Keep an eye on the current situation!

THIS neat little monitor module will allow the current flowing through some existing circuit or piece of equipment to be monitored. An audible or visible warning will then be given if it rises above or, alternatively, falls below some preset threshold value. Such a circuit will find numerous uses for power supplies, charging units and certain battery-operated devices.

The circuit draws current from the supply to the existing device so does not require a power supply of its own. The current drawn for its own operation depends on the applied voltage. However, in the prototype unit this never exceeds 100µA on standby which may be regarded as negligible. While actually operating, the current rises by that required by the warning device.

MULTI-USE

If the existing circuit is powered using a *fixed-voltage* supply, it should be possible to provide a warning when the "normal" current varies by as little as five per cent. However, if the voltage varies to some extent (such as when batteries are used) such precision will not be available.

Even so, many readers will wish to use the monitor to react to relatively large changes in current (such as when a filament lamp connected to a circuit "blows"). If the applied voltage varies by, say, 20 per cent it should still be possible to use it for this type of application.

MOTORING ON

One typical example of an application would be to check that a small motor was not being overloaded. When running normally under a light load, the current will be relatively small. As the loading increases, the speed falls and the current will rise. When it exceeds the "normal" value, the current monitor circuit could provide a warning.

The current to be monitored should fall within the range of 40mA to 2A. The operating voltage (that is, the voltage used by the existing equipment) should lie between 3V and 15V *smooth d.c.* This covers a wide range of devices. However, check this point before starting construction work.

VERSATILITY

The operating conditions are determined by a set of small on-board switches. According to their setting, a warning will be given under one of the following conditions:

- When the current rises above a preset threshold value.
- When the current falls below a preset threshold value.
- Continuously if the current rises momentarily above the threshold value since last reset
- Continuously if the current falls below the threshold value momentarily since last reset.

CIRCUIT DESCRIPTION

The complete circuit diagram for the Versatile Current Monitor is shown in Fig.1. The existing connections between the power supply and the equipment to be monitored (the load) is cut and the new ends connected to a section of terminal block TB1 on the new circuit panel.

Instead of flowing directly from the supply to the load, the current must now flow through resistor R1 (the "sensing resistor"). A small voltage (a few tens of millivolts) will then be developed across it. Although this is "lost" as far as the load is concerned, it is normally too small to have any practical effect.

The sensing resistor may be a single resistor or up to three of them connected in parallel to obtain the required value – see Table 1. It may also be made up of a closed loop of printed circuit board (p.c.b.) copper track which has been "built into" the layout specially for the purpose.

The track "resistor" (nominal value 0·05 ohm) may be appropriate for any current between 400mA and 2A. Ordinary resistors will probably be needed for a current smaller than this. Sometimes the user will need to experiment to find the best method for a given application and more will be said about this later.

IN COMPARISON

The first active part of the circuit is a low-power operational amplifier (op.amp) IC1. By minimising the current required for its own use, that drawn by the circuit as a whole is reduced. The specified unit requires only 10µA nominal.

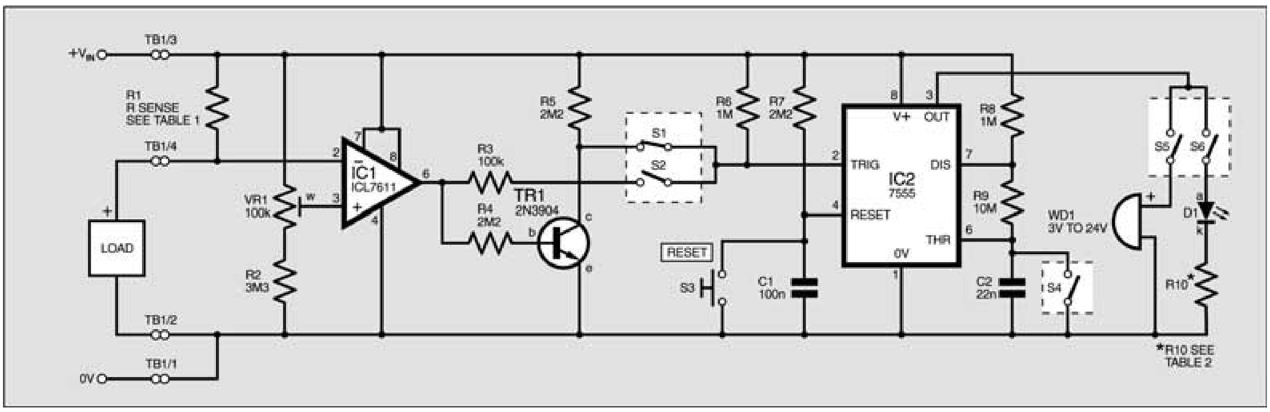


Fig.1. Complete circuit diagram for the Versatile Current Monitor.

Op.amp IC1 is used as a comparator which responds to the voltages applied to its two inputs. These are the inverting (–) input (pin 2) on the one hand and the non-inverting (+) one (pin 3) on the other. If the voltage at pin 3 exceeds that at pin 2, the output (pin 6) goes high. Otherwise, it remains low.

The inverting input (pin 2) receives the voltage developed across the load. This will be slightly less than the supply voltage – the difference being that existing across sensing resistor, R1. The non-inverting input (pin 3) receives the voltage obtained from the potential divider consisting of preset potentiometer VR1 in the upper arm and fixed resistor R2 in the lower one.

MAKING ADJUSTMENTS

With VR1 suitably adjusted, it can be arranged for the same voltage to appear at IC1 pin 3 as at IC1 pin 2 when the threshold current flows through the load. If the current drawn by the load now rises by a small margin, the voltage across sensing resistor R1 will increase slightly and that across the load will fall. The op.amp will switch on and the output (pin 6) will go high. With less than the threshold current flowing, the output will remain low.

In theory, this effect is independent of the supply voltage. This is because, if this rises or falls, the voltages at both op.amp inputs will be affected in the same proportion.

However, this is only partly true and then only with fairly small changes in voltage. The circuit will then not "see" changes in current due to a variation in voltage. The normal current may be regarded as rising or falling with small changes in applied voltage and the circuit arranged to trigger when it rises or falls for some other reason (such as a fault developing).

Imagine switch S1 is *on* and switch S2 *off* for the moment – the purpose of these switches will be described presently. Op.amp IC1's output is applied to the base of transistor TR1 via resistor R4. The low state here keeps the transistor *off* and the collector (c) is *high.* In this way, the original signal has been inverted.

Switch S1 contacts allow this state to be applied to the trigger input (pin 2) of a monostable centred on IC2, a low power timer i.c. The specified device has a very low quiescent current requirement – 60µA approximately. This, again, minimises the current required by the circuit as a whole. However, with the trigger input, pin 2, kept high nothing further happens because it is a characteristic of this type of device that triggering occurs with a *low* state.

MOMENTARY ACTION

If the current flowing through the load increases, IC1 will switch on and the high state of its output will allow current to enter the base of transistor TR1. The transistor turns on and its collector goes *low*. The low state applied to IC2 pin 2 now triggers the monostable and the output, pin 3, goes high for as long as the current remains above the threshold value.

If the current only rose momentarily above the threshold value and immediately fell again so that the high state on pin 2

Table 1

Threshold current (mA)	*Value of R1 (ohms)*
40	1
80	0·5 (2 off 1 ohm in parallel)
120	0·33 (3 off 1 ohm in parallel)
150	0·27
250	0·15
400	0·1

was restored, the monostable output would remain high for a time determined by the values of resistors R8 and R9 and capacitor C2.

Assuming that switch S4 is off for the moment so that capacitor C2 is operative, with the values specified, this time will be some 0·2 second. This sets the *minimum* operating period and is designed to prevent repeated short-period "chirping" from the buzzer near the threshold value. The timing could be increased by raising the value of resistor R9 or capacitor C2.

The monostable output can be made to operate either the buzzer WD1 or l.e.d. D1 (by closing switch S5 or S6 respectively). Resistor R10 is the l.e.d. current-limiting resistor and will be chosen according to the approximate operating voltage of the circuit. A table of values is shown in Table. 2. These allow 15mA approximately to flow through the l.e.d. at the voltage shown.

Note that when the warning device operates, this in itself causes a rise in current through the sensing resistor. It therefore assists triggering on rising current and to some extent reacts against it on falling current. However, the change is small and, in practice, is of little consequence.

INTO REVERSE

To reverse the operating condition so that triggering occurs when the current falls below the preset level, the inverting effect of transistor TR1 is removed. Switch S1 is now set *off* and S2 *on.* The logic state of IC1 output, pin 6, is now applied (via resistor R3) direct to the monostable trigger input.

If both switches S1 and S2 were to be switched on (by mistake), there would be a set of conflicting logic states and this should be avoided. If both switches were set *off* (again, in error), then IC2 pin 2 would be left unconnected or "floating". This would leave the i.c. vulnerable to damage by the pickup of stray static charge. This is avoided by including resistor R6 which maintains pin 2 in a high state under these circumstances.

The reset input (pin 4) of IC2 must be kept high to enable the i.c., resistor R7 achieves this. However, when first powered-up, this type of timer often self-triggers due to the sudden rise in voltage level. In an effort to avoid this, capacitor C1

Table 2

Supply Voltage	*Value of R10 (Ohms)*
3	67
6	270
9	470
12	680
15	820

holds pin 4 low for a short time until it has charged sufficiently through R7. With the values specified, this will take 0·2 second.

When switch S4 is on, it short-circuits timing capacitor C2. This prevents it from charging and has the effect of turning IC2 into a latch. Once triggered, the output will then remain on until cancelled by taking the reset pin 4 low. This is done by operating Reset switch S3. This switch could be situated off-board if required.

CONSTRUCTION

Construction is based on a single-sided printed circuit board (p.c.b.). The topside component layout and full-size underside copper foil track master are shown in Fig.2. This board is available from the *EPE PCB Service,* code 335.

Begin construction by drilling the p.c.b. fixing holes and then solder the i.c. sockets, terminal block and switches in position. Note that the three switches S4, S5 and S6 are part of a *four-way* d.i.l. block. This is because groups of three such switches do not appear to be available. The second one from the left is not used.

COMPONENTS

See SHOP TALK page

Resistors

R1	If required – see text and Table 1
R2	3M3
R3	100k
R4, R5, R7	2M2 (3 off)
R6, R8	1M (2 off)
R9	10M
R10	See Table 2

All 0·25W 5% carbon film, except R1

Potentiometer

VR1	100k min. multiturn preset, top adjust

Capacitors

C1	100n ceramic, 5mm pin spacing
C2	22n ceramic, 5mm pin spacing

Semiconductors

D1	3mm red l.e.d.
TR1	2N3904 *npn* transistor
IC1	ICL7611 CMOS op.amp
IC2	ICM7555IPA low power CMOS timer

Miscellaneous

S1/S2	2-way d.i.l. switch block
S3	miniature tactile push-to-make switch
S4/S5/S6	4-way d.i.l. switch block – see text
WD1	miniature solid-state buzzer – 3V to 24V operation at 10mA maximum.
TB1	4-way p.c.b. screw terminal block – 5mm pin spacing

Printed circuit board available from the *EPE PCB Service,* code 335; 8-pin d.i.l. socket (2 off); multistrand connecting wire; solder, etc.

Approx. Cost Guidance Only **£15** *excluding batts.*

If you wish to mount switch S3 off-board, the specified type of p.c.b. mounting tactile unit would probably not be convenient to use. In this case, use any other small pushbutton, push-to-make, switch.

Follow with all resistors, except R1, preset potentiometer VR1 and the two capacitors. Preset VR1 is specified as a *multi-turn* type. This is definitely advised rather than using the single-turn variety because it greatly simplifies adjustment at the end.

FILL THAT GAP

If the anticipated operating current exceeds 400mA (and up to the 2A limit), solder the link wire (a short piece of single-strand connecting wire) into the gap in the high-current loop as shown dashed in Fig.2. This puts the copper track "resistor" in the R1 position. The position reserved for fixed sense resistor(s) R1 is left empty.

It was found in the prototype unit that the p.c.b. track could be used for a current as low as 200mA. For values between 200mA and 400mA, it may therefore be worth experimenting to see whether it is necessary to use physical resistors for R1. Whether or not this is possible will depend on the width and thickness of the copper track on any particular specimen of p.c.b.

If the current to be monitored is expected to lie between 40mA and 400mA, leave the high-current link disconnected and, referring to Table 1, solder a resistor or resistors into R1's position(s) to make up the required value.

The table shows how 2 or 3 one-ohm resistors may be used to provide values of 0·5 ohm and 0·33 ohm respectively. Copper pads on the p.c.b. have been left for these. Of course, single units may be used if available.

Unfortunately, resistors of a small physical size (low power rating) in values less than one ohm are not easy to obtain. The alternative is to use units of, say, 3W rating in as small a size as possible. An additional pad has been left on the p.c.b. to allow one large unit to be mounted flat if required (see photograph).

The value of sense resistor R1 is not too critical. If the proposed threshold current is not shown in Table 1, use the nearest value.

PRECAUTIONS

Complete construction of the p.c.b. with the polarity-sensitive components, namely – transistor TR1, audible warning device WD1 and l.e.d. D1. Finally, insert the i.c.s into their sockets.

Since the i.c.s are CMOS devices, they are vulnerable to damage by static charge such as may exist on the body. To avoid possible problems, touch something which is earthed (such as a metal water tap) before unpacking them and handling their pins.

TESTING

Switch S1 on and S2 off if triggering is required on *rising* current and S1 off and S2 on if it is required on *falling* current. Switch S4 off (for momentary triggering). Switch both S5 and S6 on so that the l.e.d. and the buzzer are both in circuit. Connect the supply wires and the load to the terminal block taking care to observe the polarity. *The circuit will be damaged if the polarity is incorrect.*

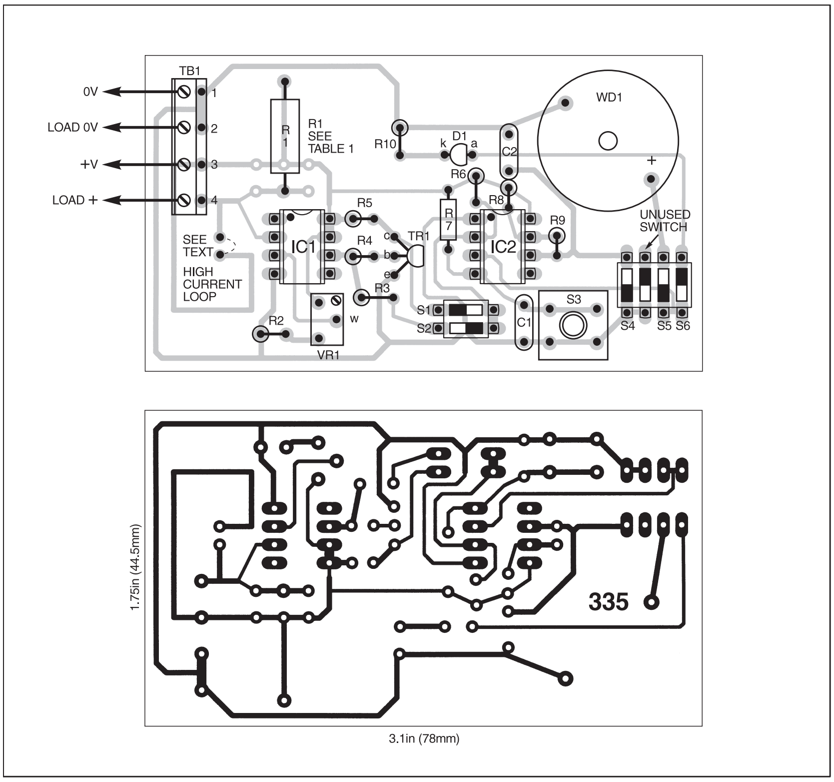
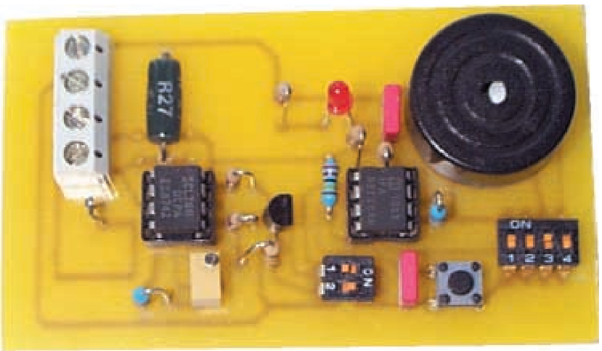


Fig.2 (above). Printed circuit board component layout and full-size copper foil master. The completed board is shown in the photograph.



Allow the external circuit (load) to operate normally. The buzzer and l.e.d. may be operating already. Adjust preset VR1 until the critical point is reached. If the switching point is not sharp (the buzzer "chirps" at the threshold value), it may be necessary to improve the degree of smoothing of the supply. In most cases, however, it will not matter.

Allow the current to rise or fall as appropriate to give the signalling condition and check for correct operation. Adjust VR1 so that this happens at a suitable point. If the circuit is operated from a battery you will need to check at the upper and lower voltage limits to arrive at the best setting for VR1.

BUILDING BRIDGES

It is possible that the high-current p.c.b. "resistor" is not physically identical to that in the prototype. Its resistance may therefore need to be modified. If using this method and the voltage drop is insufficient (see below), de-solder the link wire and include an extra short length of 20 s.w.g. bare copper wire. If the voltage drop is excessive, "bridge" sections of the track using single-strand connecting wire to reduce the resistance.

Apply a digital multitester between terminal block points TB1 and TB2 (that is, across the sensing resistor) to check the millivoltage drop at the threshold current. The circuit will work satisfactorily with a drop of only 20mV to 40mV. In the prototype unit, good operation was obtained down to 10mV.

If it is much higher than this, it will involve an unnecessary loss to the external circuit. It may then be lowered by reducing the value of sense-resistor R1. Conversely, if the voltage is too small so that the circuit fails to work, R1 should be increased.

When the circuit is working correctly, switch on S4 to check that *continuous* mode works and that it can be cancelled by pressing switch S3.

Certain loads, such as filament lamps and motors, draw a current much higher than the rated value for a short time on switching on. The current then settles to the nominal value. This should be borne in mind if connecting this type of load especially if "continuous" mode has been selected. You may then need to manually reset the circuit once the current has returned to normal. Any violent changes in the load may cause triggering anyway and you may need to press the reset switch. □

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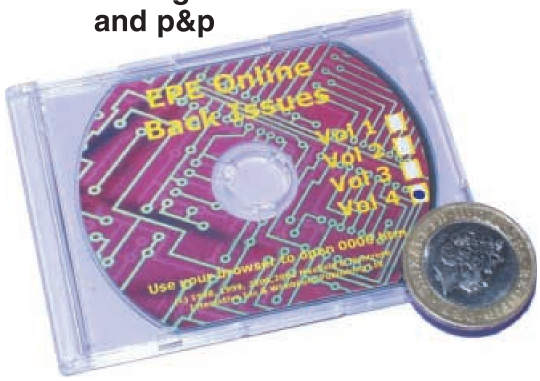

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NOV '00

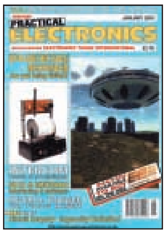
PROJECTS ● PIC Pulsometer ● Opto-Alarm System ● Sample-and-Hold ● Handclap Switch.
FEATURES ● The Schmitt Trigger–Part 1 ● Ingenuity Unlimited ● PIC Toolkit Mk2 Update V2.4 ● Circuit Surgery ● New Technology Update ● Net Work – The Internet ● FREE Transistor Data Chart.

DEC '00

PROJECTS ● PIC-Monitored Dual PSU-Part1 ● Static Field Detector ● Motorists' Buzz-Box ● Twinkling Star ● Christmas Bubble ● Festive Fader ● PICtogram.
FEATURES ● The Schmitt Trigger–Part 2 ● Ingenuity Unlimited ● Interface ● Circuit Surgery ● New Technology Update ● Quasar Kits Review ● Net Work – The Internet ● 2000 Annual Index.

JAN '01

PROJECTS ● Versatile Optical Trigger ● UFO Detector and Event Recorder ● Two-Way Intercom ● PIC-Monitored Dual PSU–Part 2.
FEATURES ● Using PICs and Keypads ● The Schmitt Trigger–Part 3 ● New Technology Update ● Circuit Surgery ● Practically Speaking ● Ingenuity Unlimited ● CIRSIM Shareware Review ● Net Work – The Internet.



FEB '01

PROJECTS ● Ice Alert ● Using LM3914-6 Bargraph Drivers ● Simple Metronome ● PC Audio Power Meter.
FEATURES ● The Schmitt Trigger–Part 4 ● Ingenuity Unlimited ● Circuit Surgery ● New Technology Update ● Net Work – The Internet ● *Free* 16-page supplement – How To Use Graphics L.C.D.s With PICs.

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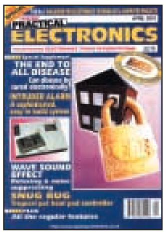

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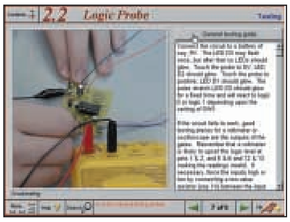
ELECTRONICS CD-ROMS

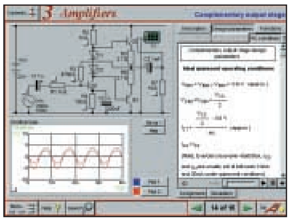
ELECTRONICS PROJECTS



Logic Probe testing

Electronic Projects is split into two main sections: **Building Electronic Projects** contains comprehensive information about the components, tools and techniques used in developing projects from initial concept through to final circuit board production. Extensive use is made of video presentations showing soldering and construction techniques. The second section contains a set of ten projects for students to build, ranging from simple sensor circuits through to power amplifiers. A shareware version of Matrix's CADPACK **schematic capture**, **circuit simulation** and **p.c.b. design** software is included.
The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

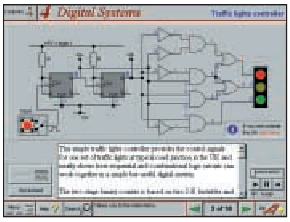
ANALOGUE ELECTRONICS



Complimentary output stage

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.
Sections on the CD-ROM include: **Fundamentals** – Analogue Signals (5 sections),Transistors (4 sections), Waveshaping Circuits (6 sections). **Op.Amps** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. **Amplifiers** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). **Filters** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). **Oscillators** – 6 sections from Positive Feedback to Crystal Oscillators. **Systems** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

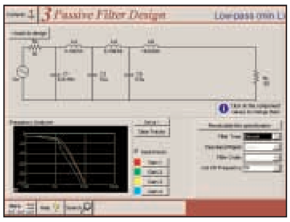
DIGITAL ELECTRONICS



Virtual laboratory – Traffic Lights

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (opposite), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.
Covers binary and hexadecimal numbering systems, ASCII, basic logic gates, monostable action and circuits, and bistables – including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units.

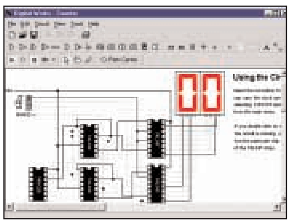
FILTERS



Filter synthesis

Filters is a complete course in designing active and passive filters that makes use of highly interactive virtual laboratories and simulations to explain how filters are designed. It is split into five chapters: **Revision** which provides underpinning knowledge required for those who need to design filters. **Filter Basics** which is a course in terminology and filter characterization, important classes of filter, filter order, filter impedance and impedance matching, and effects of different filter types. **Advanced Theory** which covers the use of filter tables, mathematics behind filter design, and an explanation of the design of active filters. **Passive Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev ladder filters. **Active Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev op.amp filters.

DIGITAL WORKS 3.0

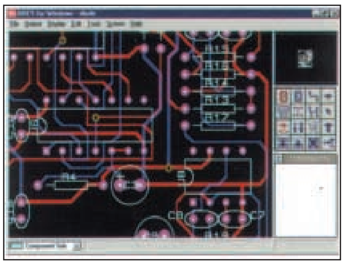


Counter project

Digital Works Version 3.0 is a graphical design tool that enables you to construct digital logic circuits and analyze their behaviour. It is so simple to use that it will take you less than 10 minutes to make your first digital design. It is so powerful that you will never outgrow its capability.

- Software for simulating digital logic circuits
- Create your own macros – highly scalable
- Create your own circuits, components, and i.c.s
- Easy-to-use digital interface
- Animation brings circuits to life
- Vast library of logic macros and 74 series i.c.s with data sheets
- Powerful tool for designing and learning

ELECTRONICS CAD PACK



PCB Layout

Electronics CADPACK allows users to design complex circuit schematics, to view circuit animations using a unique SPICE-based simulation tool, and to design printed circuit boards. CADPACK is made up of three separate software modules. (These are restricted versions of the full Labcenter software.) **ISIS Lite** which provides full schematic drawing features including full control of drawing appearance, automatic wire routing, and over 6,000 parts. **PROSPICE Lite** (integrated into ISIS Lite) which uses unique animation to show the operation of any circuit with mouse-operated switches, pots. etc. The animation is compiled using a full mixed mode SPICE simulator. **ARES Lite** PCB layout software allows professional quality PCBs to be designed and includes advanced features such as 16-layer boards, SMT components, and an autorouter operating on user generated Net Lists.

"C" FOR PICMICRO MICROCONTROLLERS

C for PICmicro Microcontrollers is designed for students and professionals who need to learn how to use C to program embedded microcontrollers. This product contains a complete course in C that makes use of a virtual C PICmicro which allows students to see code execution step-by-step. Tutorials, exercises and practical projects are included to allow students to test their C programming capabilities. Also includes a complete Integrated Development Environment, a full C compiler, Arizona Microchip's MPLAB assembler, and software that will program a PIC16F84 via the parallel printer port on your PC. (Can be used with the *PICtutor* hardware – see opposite.)
Although the course focuses on the use of the PICmicro series of microcontrollers, this product will provide a relevant background in C programming for any microcontroller.

PRICES

Prices for each of the CD-ROMs above are:

Hobbyist/Student	£45 inc VAT
Institutional (Schools/HE/FE/Industry)	£99 *plus* VAT
Institutional 10 user (Network Licence)	£199 *plus* VAT

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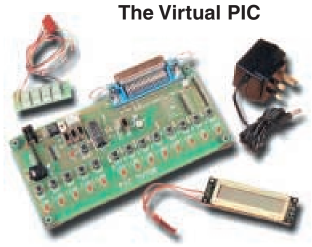
Interested in programming PIC microcontrollers? Learn with PICtutor

The Virtual PIC



Deluxe PICtutor Hardware

This highly acclaimed CD-ROM by John Becker, together with the PICtutor experimental and development board, will teach you how to use PIC microcontrollers with special emphasis on the PIC16x84 devices. The board will also act as a development test bed and programmer for future projects as your programming skills develop. This interactive presentation uses the specially developed **Virtual PIC Simulator** to show exactly what is happening as you run, or step through, a program. In this way the CD provides the easiest and best ever introduction to the subject. Nearly 40 Tutorials cover virtually every aspect of PIC programming in an easy to follow logical sequence.

HARDWARE
Whilst the CD-ROM can be used on its own, the physical demonstration provided by the **PICtutor Development Kit**, plus the ability to program and test your own PIC16x84s, really reinforces the lessons learned. The hardware will also be an invaluable development and programming tool for future work.
Two levels of PICtutor hardware are available – Standard and Deluxe. The **Standard** unit comes with a battery holder, a reduced number of switches and no displays. This version will allow users to complete 25 of the 39 Tutorials. The **Deluxe** Development Kit is supplied with a plug-top power supply (the **Export** Version has a battery holder), all switches for both PIC ports plus l.c.d. and 4-digit 7-segment l.e.d. displays. It allows users to program and control all functions and both ports of the PIC. All hardware is supplied **fully built and tested** and includes a PIC16F84.

PICtutor CD-ROM
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Institutional 10 user (Network Licence) .£199 *plus* VAT

HARDWARE
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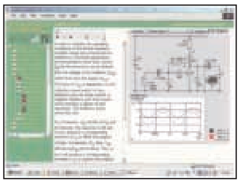

Circuit simulation screen

Provides an introduction to the principles and application of the most common types of electronic components and shows how they are used to form complete circuits. The virtual laboratories, worked examples and pre-designed circuits allow students to learn, experiment and check their understanding. Version 2 has been considerably expanded in almost every area following a review of major syllabuses (GCSE, GNVQ, A level and HNC). It also contains both European and American circuit symbols. Sections include: ***Fundamentals:*** units & multiples, electricity, electric circuits, alternating circuits. ***Passive Components:*** resistors, capacitors, inductors, transformers. ***Semiconductors:*** diodes, transistors, op.amps, logic gates. ***Passive Circuits. Active Circuits.*** *The Parts Gallery* will help students to recognise common electronic components and their corresponding symbols in circuit diagrams. Selections include: ***Components, Components Quiz, Symbols, Symbols Quiz, Circuit Technology.***
Included in the Institutional Versions are multiple choice questions, exam style questions, fault finding virtual laboratories and investigations/worksheets.

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- ☐ C For PICmicro Microcontrollers
- ☐ PICtutor
- ☐ Electronic Circuits & Components V2.0

Version required:
- ☐ Hobbyist/Student
- ☐ Institutional
- ☐ Institutional 10 user
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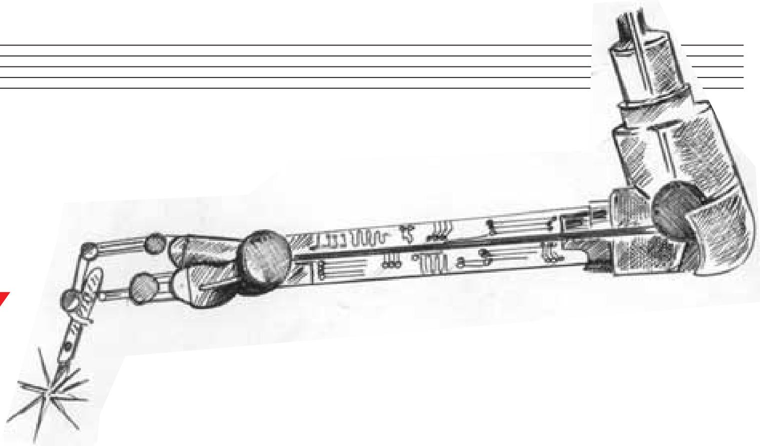


ALAN WINSTANLEY
and IAN BELL

This month, our surgeons attempt to unravel the confusion surrounding the choice of fuse ratings, plus a positive answer to electrolytic capacitors.

Utterly Con-fused

An *EPE* regular reader, ***Malcolm Wiles,*** asks:

*"The 'fuse ratings' letter of the month (*Readout*, December 2001) was interesting, but I have to say a bit over my head. From the info. given I would not be able to construct a suitable tester.*

What's a peak reading a.c. ammeter or an audio-type PPM EMC-type quasi-peak voltmeter? As this is an important safety issue, I wonder if your circuit surgeons would consider going into this topic in a bit more detail sometime?"

Help is at hand, Malcolm. I thought it would be interesting to start by examining the problems faced by engineers working in the power generation industry, which might make it easier to relate to the ordinary fuses that we use ourselves every day. Then we'll examine the basic issues of trying to determine the best values for fuses used in home-built projects.

Imagine an electrical circuit breaker on an enormous scale, such as one used in an electricity power station that is used to control thousands of amperes and tens of thousands of volts. As readers will know, high voltages can "jump" quite a distance (many metres), which is why it is always extremely dangerous to go or play near any high-voltage equipment or pylons: even though you cannot see any perceptible "circuit", high voltage arcs can jump through the air and cause electrocution.

The same principle applies within a fuse, whose job it is to disconnect the supply when a fault condition arises. We all rely on fuses to melt in good time and disconnect the supply; in the UK a fuse is always built into a standard mains plug but this really only protects the mains cord. A fuse is needed in the equipment to prevent an electrical fire occurring.

When you remember that an ordinary fuse ultimately does the same job as an on-off switch (but isn't designed as one!), the same problems that are faced by "switchgear" also apply to fuses themselves. In the electricity power industry, fault currents that switchgear have to cope with can reach a quarter of a million amperes at hundreds of megavolts: when a circuitbreaker is opened, the contacts separate and interrupt the current.

This generates an electric arc between the two contact points. It is possible for this arc to cause a current to *continue to flow*, because of the ionisation that takes place around it. A hot ribbon of electrically conducting vapour can be created so that although the switch contacts are "open", the circuit hasn't been interrupted properly.

In a modern power station, the circuit breakers are gas-filled to prevent this. Whilst in older systems, the switchgear generated large arcs several feet long, accompanied by a deafeningly loud bang. Some of the largest circuit breakers used a blast of air to open the contacts and also blow out the arc!

The problem of extinguishing that arc affects the design and choice of an ordinary fuse: on a much smaller scale, when a fuse melts, will it really interrupt the circuit properly? Will it be able to handle the magnitude of the fault current or will it explode like a burning resistor?

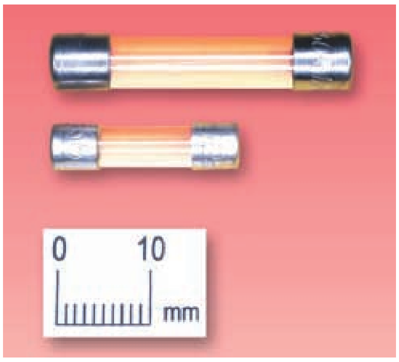
Or will it arc internally across the gap, even for a short time, so that the circuit is not properly isolated? This could allow the electrical fault to cause more damage to the apparatus, especially if semiconductors are involved, leading to component failure elsewhere.

Leaps and Volts

The first aspect we consider is the **voltage rating** of a fuse. If only the current is important, then why is a voltage rating also marked on fuses? What difference does it make? American users ask if it is all right to use a 230V a.c. fuse instead of a 125V a.c. fuse, and Americans currently in the UK wonder how safe is it to use their 125V fuses on the British 230V supply.

Strictly speaking, a fuse's voltage rating should not be lower than the circuit voltage itself, but it can safely be ***higher.*** Imagine a cartridge fuse designed for use in a 6V a.c. system (I don't think there's such a thing, but imagine anyway). If it were used in a 230V a.c. mains circuit instead, when a fault occurred it would not "melt" in a controlled way but would probably explode instead.

The voltage value relates to a fuse's ability to interrupt a circuit efficiently without internal arcing or other forms of failure (shattering, explosion), and when a melting fuse is racing a power semiconductor to destruction then microseconds can matter. So a 230V a.c. fuse can be used on a 125V a.c. circuit, but not the other way round.



A comparison between a miniature 20mm fuse and a 1¼in. (3AG) type. The smaller type is universally used in most European equipment

The manufacturer Siemens states that it is acceptable, for example, to use a 600V fuse in a 480V circuit, but a 250V fuse could not be used in a 480V circuit (**www.sea.siemens.com/training/step2000/courses**). Nevertheless, people do use wrong voltage ratings in circuits at times, which means that they will not have the optimum protection.

In lower-output circuits, e.g. a d.c. supply, since the impedance of the circuit may restrict the maximum current that can flow anyway, then to ensure that the fuse will still blow properly should a fault current flow, a *lower voltage* fuse may be specified at that time. Equipment manufacturers would take account of such factors.

Currently Confused

The fuse's current rating is obviously the most critical aspect. There are actually several current ratings involved. Note that

the value printed on a fuse is its ***current carrying rating***, i.e. the amount of current it can carry continuously without breaking! It is ***not*** the value at which the fuse melts! It is unreliable to constantly operate a fuse at its maximum rating, as it can age over time and then blow prematurely.

The next question is usually, "at what current will the fuse actually melt?" This depends on many factors including the duration of the fault and, very importantly, the ambient temperature around the fuse.

Overall the melting point is a function of I^2t measured in ampere-squared seconds, which is why you cannot simply say that the fuse will blow at *x* amperes. It also takes *time* to melt and this in turn depends on several conditions including duty cycles, how much heat is being dissipated away from the fusewire in between times, and surge currents.

A 1in. 3A ceramic fuse as fitted into most UK mains plugs. They may be sand-filled to prevent internal arcing.

A ***breaking capacity*** figure may be quoted, which indicates the maximum instantaneous fault current at which the fuse will safely melt without rupturing (exploding). You can however calculate reasonable fuse values without too much difficulty, as I'll explain next.

The *Teach-In 2002 Power Supply* (see November 2001 issue) used a 250mA quick-blow fuse on the mains primary. Since the project was built, the fuse has actually blown once due to nuisance tripping, probably caused by a surge on the d.c. side when the power pack was hot and the fuse was more "sensitive".

A crude way of choosing a fuse is to estimate the currents in the mains primary circuit by using *P=IV*, because the power input is the same as the power output by the mains transformer. Then select a fuse from there (say, 50% higher than the maximum working current, being mindful of mains wiring ratings etc. as well).

It was estimated that under 100mA or so maximum mains current would flow in normal use and so a 250mA 250V 20mm quick blow fuse was chosen. The mains plug is fitted with a 3A 1in. ceramic fuse as well, which will disconnect the supply in the event of mains power cord faults.

Clearly, too high a fuse value would be a fire hazard, but too low a figure results in annoying tripping. If necessary, use a slow-blow fuse to protect against switch-on surges caused when the smoothing capacitors charge up for the first time. Glass anti-surge fuses often contain a coiled fusewire inside.

Better Fuses

A better way of fusing a circuit is to examine what is really going on in the circuit itself. In the case of a d.c. power supply, a higher r.m.s. current flows around the secondary and bridge rectifier/smoothing capacitor circuit than is actually "seen" by the load at the d.c. output. As stated in the constructional article, this means that the total d.c. load allowed is only about 600mA or so, but higher secondary r.m.s. figures (1A) will be reflected by the current flowing in the primary.

It is possible to examine this by looking at the actual voltage developed across a series resistor in the mains lead: the *Readout* correspondent suggested using test equipment across a 0·1 ohm resistor, powering the whole lot via a mains isolation transformer. This is a very accurate method but is probably a bit risky for the average constructor. The most practical advice I have seen is to use a True RMS meter to measure the true r.m.s. current flowing in the mains side, then choose a fuse 50 per cent higher. (Reference: *The Art of Electronics, Horowitz and Hill*). This again is quite ambitious for many hobbyist designers.

The US manufacturer Littelfuse appears to suggest that you could take the maximum operating current and calculate a fuse by derating it 25% at 25°C to avoid nuisance blowing, so a 10A fuse would protect a 7·5A load current. Therefore, the *Teach-In 2002 Power Supply* would require a slow-blow fuse of say 125mA or 160mA, both of which are readily available. I feel my 250mA quick blow type is acceptable protection though. Designers are limited anyway in their choice, due to the range of fuse values they can buy off-the-shelf in the first place.

A 20mm glass anti-surge fuse; the coil of fusewire prevents the fuse from melting due to any switch-on surge or inrush current.

As for the types of fuses themselves, in Europe and beyond we tend to use metric 20mm × 5mm diameter types for currents up to roughly 10A or so. These are found universally within electronics equipment. Some fuses are filled with silver sand to extinguish the arc – an HRC (high rupturing capacity) fuse is sand-filled and is generally manufactured to tighter tolerances.

A larger size is the 1¼in. × ¼in. diameter type which is available in higher current ratings (from 60mA all the way up to 32 amperes). In the USA these are known as 3AG types (AG means "Automobile Glass"). The smaller 8AG fuses measure 1in. x ¼in.

Again in Europe, letters may be used to designate their speed, with "F" meaning quick blow, and "T" meaning anti-surge. These letters are stamped on the metal end caps. Surface mount and semiconductor fuses are now available as well. *A.R.W.*

● An excellent document entitled *"Fuseology"* has been published by the fuse manufacturer Littelfuse, available for download as a PDF from **www.littelfuse.com** and definitely worth reading.

Electrolytics Unravelled

Tamer Salem emailed to ask *"Electrolytic capacitors have positive and negative (polarised) terminals, so how do they pass a.c. current, as the a.c. is alternating between positive (+ve) and negative (–ve)?"*

The simple answer is that electrolytic capacitors are not used where they can be exposed to the incorrect polarity – so they *must not be used* in circuits in which an a.c. signal will apply reverse polarity, however there are many situations where they can be used safely.

Electrolytic capacitors achieve their high density of capacitance per volume because the insulating layer (dielectric) is very thin. This is achieved using electrolytically-deposited aluminium oxide rather than, for example, a thin sheet of plastic held between two metal foils.

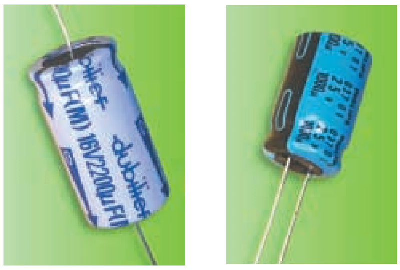
However, the electrolytic nature of the dielectric means that it can be broken down electrically, which is what happens if you reverse the connections. The consequences can be severe, including fire and explosions – at the very least the capacitor will be damaged.

A typical application of electrolytic capacitors is in power supply smoothing. Electrolytic capacitors can be connected to the outputs of rectifiers because the rectification diodes ensure the signal polarity does not change, only the voltage amplitude varies.

Electrolytics can also be used to couple or filter a.c. signals (in amplifiers etc.) as long as the d.c. bias conditions in the circuit ensure that the polarity is never reversed. In this sense the capacitor will *"pass a.c."* but the bias ensures that the terminals are not *"alternating between +ve and –ve"*.

In oscillators for which electrolytic capacitors are suitable, the capacitors are charged and discharged as the circuit switches but again, the polarity does not change. It is possible for the plates of an electrolytic (or other) capacitor to be outside the supply voltage range (e.g. below 0V in a single supply system) but this does not require a change of polarity.

For example, if an electrolytic capacitor is charged to +5V, with 0V on the negative plate and 5V on the positive plate, and then the positive plate is quickly switched to 0V with the negative plate free to vary, the negative plate will fall to –5V, but the polarity of the voltage across the electrolytic will not have changed. *I.M.B.*

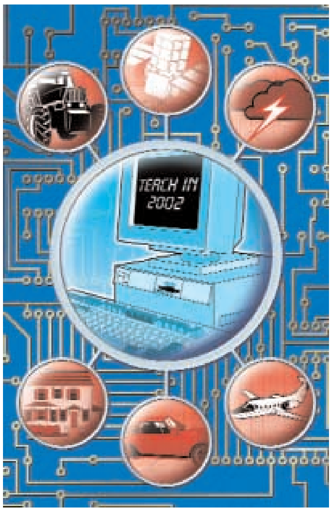


Two examples of electrolytics. The axial type (left) has "arrows" pointing to its negative (–) end. The radial type (right) has a band or arrows on one side to indicate its negative (–) lead. Some electrolytics indicate their positive connection with a plus (+) symbol.

EPE Tutorial Series

TEACH-IN 2002

Part Four – Good Vibrations – Measuring Stress, Strain and Vibration



IAN BELL AND DAVE CHESMORE

Making Sense of the Real World: Electronics to Measure the Environment

LAST month, prior to examining humidity sensors, we discussed op.amps in relation to their offset voltages and bias currents and how these can affect the accuracy of sensor output measurements.

This month we examine strain sensors, which typically produce extremely small changes in output signal. Such small signals can easily be distorted by other external conditions. So it is appropriate to first discuss various ways in which signal errors and imperfections can be minimised. We then examine strain sensors themselves and also look at piezoelectric vibration sensors.

Then, in Lab Work, we describe how to build a simple rain intensity meter, and a novel knocker circuit.

SIGNALS AND NOISE

Sensors produce signals, that is varying voltages or currents, whose variation carries information about whatever we are sensing or measuring. These signals, and the signals within the circuits connected to the sensors, can take a variety of forms and are subject to various types of error and imperfection.

Last month we looked at the problem of offsets, which are basically d.c. or very low frequency errors. At frequencies higher than the slowly changing offsets, unwanted signals are usually referred to as **noise** or **interference** (see Figs. 4.1 to 4.4 for examples of various forms of noise or error). This may comprise random variations in the signal voltage or may have a very specific frequency, such as 50Hz/60Hz mains hum, for example (Fig.4.4). We will look at random noise in more depth in a later part.

DIFFERENTIAL SIGNALS

The signals we have just discussed are called **single-ended** because a single wire (other than ground) is used to carry the signal. A possible problem with this approach occurs when the wire carrying the signal may pick up noise, acting as an aerial and picking up, say, radio frequency interference or mains hum.

To overcome this we can use a **differential** signal, which is carried on two wires (i.e. two voltages V_1 and V_2) other than

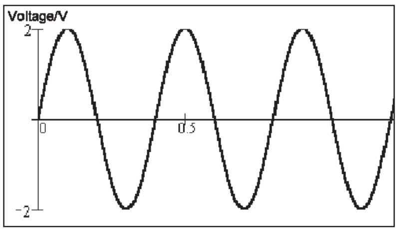


Fig.4.1. A signal varying around 0V. The peak value is 2V and the peak-to-peak value is 4V. The frequency is 2.5kHz. There is no noise or error present, although the digitised sampling steps are apparent.

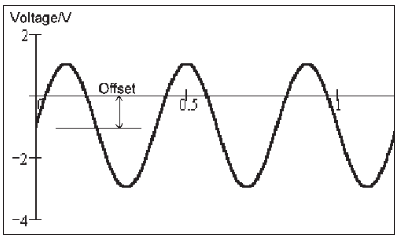


Fig.4.2. The signal from Fig.4.1 with a –1V offset. If you consider the signal rather than the offset the true peak value is still 2V, even though the signal "peaks" at +1V and –3V.

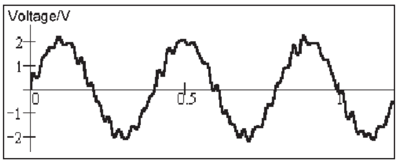


Fig.4.3. The signal in Fig.4.1 with superimposed noise of a higher frequency than the signal.

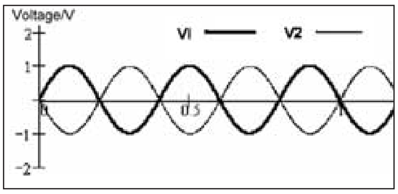


Fig.4.5. Differential signal. The signal is the difference between V_1 and V_2 and therefore has a peak value of 1V and a peak-to-peak value of 2V.

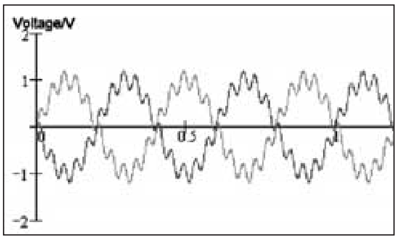


Fig.4.6. Differential signal with a common mode noise. The difference between these waveforms is the same as the signal in Fig.4.5.

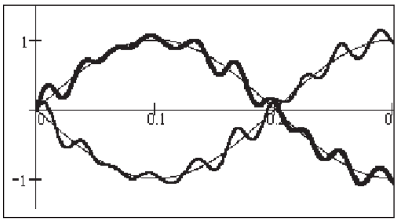


Fig.4.7. Zooming in on the first part of Fig.4.6 to see more clearly that the noise is common mode – i.e. the error goes in the same direction on both waveforms.

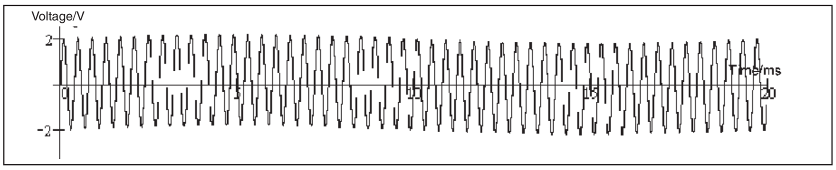


Fig.4.4. The signal in Fig.4.1 with superimposed noise of a lower frequency than the signal. This is about 0.2V peak of 50Hz mains hum. Note that the waveform is displayed over a longer period than Fig.4.1 so that the noise is more obvious to see.

ground. Fig.4.5 shows a differential signal with a peak voltage of 2V and a peak-to-peak voltage of 4V. Note that this is the *difference* between V_1 and V_2.

With a differential signal, if the signal voltage on one wire increases then the signal voltage on the other wire decreases by exactly the same amount. The actual signal is equal to the *difference* in the voltages on the two wires measured with respect to ground. So if the two voltages on the two wires are V_1 and V_2 the signal V_s is $(V_1–V_2)$.

If the two wires run closely parallel, then the same error (e.g. mains hum, interference, etc.) will occur on each wire. If this error is δ (delta) then the voltage on wire 1 will become $V_1 + \delta$ and the voltage on wire 2 will become $V_2 + \delta$. The signal is the difference between the two wires, that is:

$$((V_1 + \delta) - (V_2 + \delta)) = (V_1 - V_2)$$

which is the same as without the error! This is illustrated in Fig.4.6 and Fig.4.7.

The error voltage δ is common to both halves of the differential signal. It is therefore called a **common mode** voltage and noise of this form is called **common mode noise**. If the voltages on the two wires are V_1 and V_2 the common mode signal V_{cm} is $(V_1 + V_2) / 2$ (i.e. the average of the voltage on the two wires).

Differential signals quite often have d.c. common mode voltages, for example a 2V peak-to-peak sine wave differential voltage with a 1·5V common mode d.c. signal is shown in Fig.4.8.

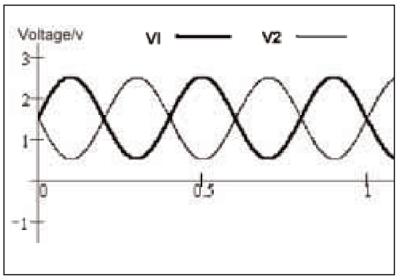


Fig.4.8. 2V peak-to-peak differential signal with 1.5V common mode voltage.

DIFFERENTIAL SIGNALS AND SENSORS

Differential signals are used quite commonly in sensor systems. They have applications such as temperature compensation and reducing the effects of interference if signals have to travel over relatively long wires. Closely spaced long wires carrying a differential signal will pick up interference, but this will influence both wires equally and hence appear as a common mode signal.

For temperature compensation we arrange two sensors so that only one is subject to the condition we are measuring, but both are affected in the same way by temperature changes. Alternatively, we can use two sensors, configured so that the output of one will increase as other decreases under the influence of the measured quantity, but with both experiencing the same temperature.

In both cases the unwanted changes in sensor output due to temperature changes appear as a *common mode* signal, whereas the measured quantity is *differential*.

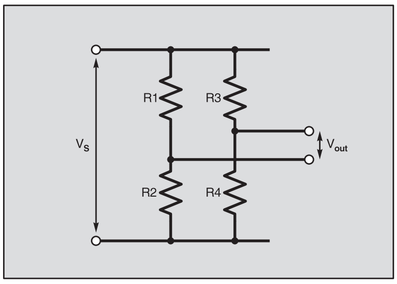


Fig.4.9. Basic Bridge Circuit

BUILDING BRIDGES

A common approach to generating a differential signal from a sensor, or sensor combination, is to use a **bridge** circuit. In its most basic form, the bridge circuit consists of two resistive potential dividers as shown in Fig.4.9.

The four sections of the bridge (shown here as four resistors, R1 to R4) are generally referred to as the **arms** of the bridge. The sensor or sensors may be in any one or more of the arms. Bridges do not have to be simply resistive, we can make capacitive and inductive bridges too.

A voltage, V_s, is applied across the bridge, in many cases this is simply the power supply of the circuit, although it may be some other voltage and may even be an a.c. signal. The output voltage is the *difference* between the two potential divider voltages.

In the simplest bridge circuit only resistor R1 is a sensor, the other resistors are fixed and typically all have the same value, equal to the nominal value of the sensor.

For temperature compensation, R1 is the active sensor and R2 is another sensor isolated from the measurement quantity, but at the same temperature as R1.

For some sensor systems, such as strain measurement, it is possible to arrange two sensors that have equal and opposite responses to the quantity being measured (i.e. one increases in resistance and the other decreases as the quantity changes).

In such cases we can build push-pull bridges in which either R1 and R2 are opposite sensors and R3 and R4 are fixed (single push-pull), or in which R1 and R4 are equal (say) negative-response sensors and R2 and R3 are equal (in this case) positive-response sensors (double push-pull). Single push-pull provides twice the output signal of a simple bridge and double push-pull four times as much.

SOURCE RESISTANCE AND LOADING

When connecting sensors or bridge circuits to amplifiers (or other circuits) we need to be aware of the possible problem of loading the sensor or bridge with the amplifier input. If a sensor outputs a voltage we can view it as an ideal voltage source (V_s) in series with a resistance (R_s), called the **internal** or **source** resistance. This is

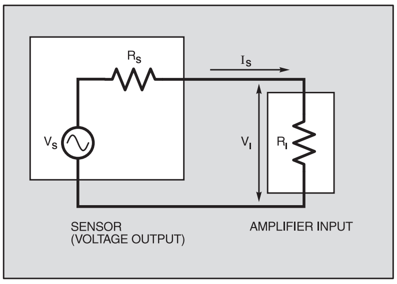


Fig.4.10. Thevenin equivalent circuit for sensor and amplifier configuration.

connected to the amplifier input that has a certain input resistance (R_I). This is illustrated in Fig.4.10.

Observant readers will notice that R_S and R_I form a potential divider. Thus the voltage at the amplifier input, taking loading into consideration, is given by:

$$V_I = \frac{R_I}{(R_S + R_I)} \; V_S \qquad \text{(Equation 1)}$$

We get this equation by using Ohm's Law to get the current (I_s) through the two resistances (V_S divided by the total resistance ($R_s + R_I$) and applying Ohm's Law again to get the voltage drop across R_I (by multiplying R_I by this current).

From the equation we see that if we want V_I to be as large as possible then R_I must be much larger than R_S (we are assuming R_S is fixed for a given sensor, but R_I is influenced by our choice of amplifier). If R_I is very much larger than R_S then the load voltage is effectively equal to the source voltage.

It may seem that Fig.4.10 implies that the sensor generates the voltage signal. This is not necessarily the case, as we can represent a wide variety of circuit configurations in the form shown in this figure. The representation of a circuit as a voltage source and a resistance is known as the **Thevenin equivalent circuit**.

Let's look at finding an equivalent circuit. Consider a sensor whose resistance changes from 100kΩ to 200kΩ as the quantity being sensed varies (e.g. it could be a thermistor or a light dependent resistor, such as those used in Lab Works 1 and 2). We could wire this sensor into a potential divider connected to an amplifier as shown in Fig.4.11.

In an ideal circuit the potential divider voltage might vary from 4·80V to 6·86V as the sensor resistance varies. We will assume that the amplifier level shifts and amplifies this 2·06V variation to give an

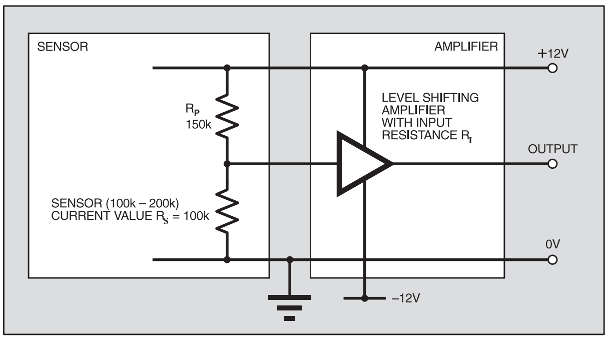


Fig.4.11. Sensor and amplifier.

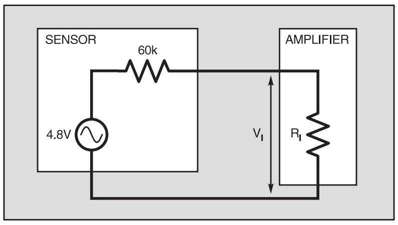


Fig.4.12. Equivalent circuit for Fig.4.11 when the sensor resistance is 100kΩ.

output using the full 0V to 12V range of the supply. The details of its implementation are not important, except to note that we know the input resistance of the amplifier is R_I.

The values in the equivalent circuit shown in Fig.4.12 vary depending on the resistance value, so we will just look at what happens when the sensor has a value of 100kΩ.

WORKED EXAMPLE

The value of V_s is simply the open circuit voltage – i.e. the output voltage with no load, which we have already mentioned. This is easy to calculate in this case, as it is simply the potential divider voltage. When the sensor has a value of 100kΩ this is 4·80V as previously stated.

The value of R_S is a little more difficult. It is calculated by taking the short circuit output current from the original circuit and finding the resistance that would give the same short circuit current with V_s.

The short circuit output current for our potential divider occurs when we connect the potential divider point to ground. The current is 12V/150kΩ = 80mA. To get 80mA with 4·8V we need 4·8V/80mA = 60kΩ. So R_s = 60kΩ when the sensor has resistance 100kΩ. Note that in this case the value of R_s is equal to the parallel combination of R_I and the sensor.

We can now draw the equivalent circuit as shown in Fig.4.12. From this, and using the loading equation (Equation 1) from earlier, we can see effect of R_I. If R_I is, say, 5kΩ we get 4·8 × 5/(60 + 5) = 0·37V input to the amplifier rather than the 4·8V we would hope for. However, if we use an amplifier with an R_I of 50MΩ we get 4·79V at the amplifier input, pretty close to what we want. For other sensor resistance values we could perform similar calculations.

In this example we could use the equivalent circuit with the voltage source even though the sensor itself does not generate a voltage. Electronics designers often use equivalent circuits. Using sets of rules and often some approximations, they transform a "real" circuit into a simpler equivalent that behaves in the same way (at least with respect to something they are interested in).

Equivalent circuits contain fewer "components" (they are abstract rather than real components) which makes subsequent calculations a lot easier. Furthermore, comparisons between different circuits transformed into the same equivalent circuit are easy to make. The Thevenin equivalent circuit is good example of this approach as all "sources" are represented in a similar way.

PANEL 4.1. Stress and Strain

If we consider a metal rod of length L metres (m) and cross-sectional area A square metres (m^2) as shown in Fig.4.13 and we apply a force F Newtons (N) in such a way as to pull the rod apart, we can define the tensile stress as

$$\text{Tensile Stress} = \frac{F}{A}$$

the units are in Newtons per square metre Nm^{-2}

The strain is defined as the change in length due to the force divided by the length, i.e. the fractional change in length. The change in length is usually written as ΔL where Δ means change. So the tensile strain is defined as:

$$\text{Tensile Strain} = \frac{\Delta L}{L}$$

this has no units

Application of a force in the opposite direction so as to push the rod together gives compressional stress and compressional strain. A third form, shear stress/strain is obtained when we try to push the material sideways. In this case, the shear strain is defined as:

$$\text{Shear Strain} = \frac{\Delta X}{L}$$

where ΔX is the change in width and L is the width of the object. If we plot on a graph the change in strain for various values of stress we get a straight line until the point where necking occurs, i.e. the material suddenly becomes softer and thinner. The material finally breaks if stress is further increased.

The slope of the line is called the modulus of elasticity or Young's Modulus (E) and is equal to stress divided by strain. Different materials have different values of E. For example, aluminium has E = $6{\cdot}89 \times 10^{10}$, copper $11{\cdot}73 \times 10^{10}$ and polyethylene (a form of plastic) $3{\cdot}45 \times 10^{8}$.

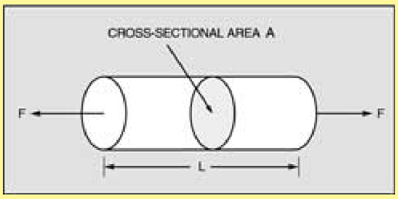


Fig.4.13. Forces on a rod of metal.

FORCE EFFECTS

Having highlighted how small signals can be kept relatively free from errors and imperfections, we can now examine how small levels of stress and strain in materials can be measured.

Measuring force effects on materials is one of the most common applications for sensors. For example, all weighing machines rely on the weight of the object to be determined to produce a force that can be measured.

Pressure sensors operate in a similar manner, whereby the pressure difference between one side of a diaphragm and the other causes the diaphragm to move and experience a force. Accelerometers use changes in force caused by changes in speed.

In most cases, these forces cause changes in an elastic material, which in turn change its resistance or other properties, the change can then be measured to obtain the force.

STRESS AND STRAIN

Let's look first at the effects of applying a force to a solid object such as a bar of metal. Such a force is called *stress* but it is not the same stress we get when our computer stops working yet again, although we may very well want to apply considerable force to the computer!

If we look at the constitution of a metal at the atomic level, it is a lattice of atoms held together in equilibrium and the spacing between atoms determines the physical size of the object. When we apply a force, the atoms will re-arrange themselves in order to keep equilibrium. The atomic spacing will change and so will the physical dimensions, i.e. the object will *deform*. This resulting deformation is called a *strain*. Panel 4.1 and its Fig.4.13 give a detailed description of stress and strain.

STRAIN GUAGES

So how do we create a sensor that can measure strain? As you may know, a length of wire of any metal has a resistance (R_0) which depends on its length (L_0), cross-sectional area (A_0) and resistivity (ρ in Ωs) as follows:

$$R_0 = \rho \frac{L_0}{A_0}\,\Omega \qquad \text{(Equation 2)}$$

When the wire is stressed, its length will *increase* by ΔL and its area *decreases* because the overall volume of the wire remains constant. Without going through the mathematics, the approximate change in resistance due to the length and area changes is:

$$\Delta R \approx 2R_0 \frac{\Delta L}{L_0} \qquad \text{(Equation 3)}$$

This equation shows that the strain ($\Delta L/L_0$) is converted directly into a change in resistance. A sensor based on this principle is called a **strain gauge** and is a length of metal wire or foil glued to the object whose strain is to be measured. When the object is deformed so is the strain gauge.

A typical strain gauge is illustrated in Fig.4.14 and consists of a wire or foil arranged in a specific pattern. The idea is to

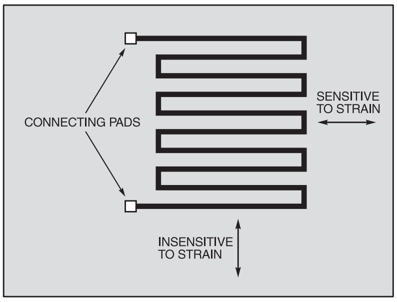
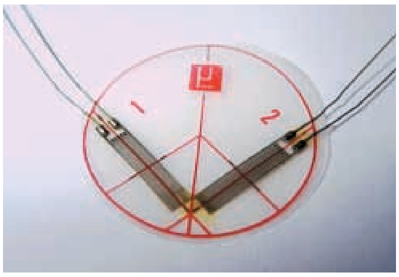


Fig.4.14. Layout of a typical strain gauge



Example of a dual strain gauge module.

cause the wire to change length by as much as possible when a force is applied in one direction only, i.e. it is unidirectional. The pattern is designed so that the length of the strain gauge is as long as possible.

Before we start using strain gauges in circuits there is one more thing to consider – the **gauge factor** (GF). The GF of a strain gauge determines its operating characteristics and is an accurate measure of the strain-resistance relationship we have just described (Equation 3). Impurities in the metal, and indeed the type of metal, lead to small deviations from the ideal and the GF takes this into account. GF is defined as:

$$GF = \frac{\Delta R/R}{\Delta L/L} \quad \text{(Equation 4)}$$

Gauge factor is always close to a value of two for metal strain gauges but can be as high as 10 for special alloys or gauges made of carbon. The larger the value of GF the better, since we get a larger change in resistance for a given value of strain. Typical resistance values for commercial strain gauges are 60Ω, 120Ω, 240Ω, 500Ω and 1000Ω.

How much does the resistance of a strain gauge change by? Strain values are usually very small as it requires a lot of force to stretch a wire. A typical value might be 0·001, corresponding to a change of 1mm in a length of one metre, and would lead to a change in resistance of only 0·24Ω for a 120Ω strain gauge. Such small resistance changes are not easy to measure and can lead to many difficulties.

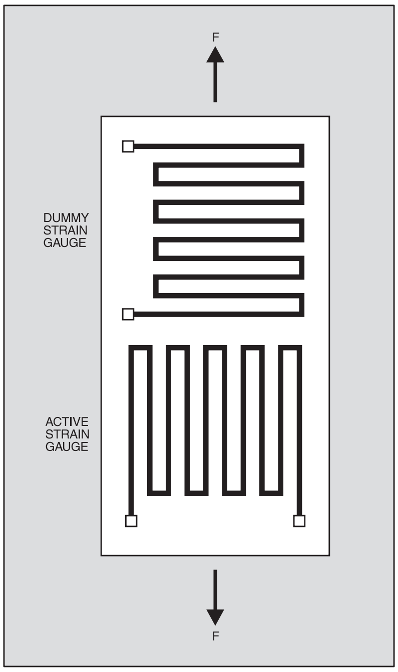


Fig.4.15. Using a dummy strain gauge for temperature compensation.

PANEL 4.2. Strain Gauges in Use

Strain gauges are delicate components that need to be handled very carefully. They usually have two very fine wires and are supplied with miniature self-adhesive printed circuit boards carrying two copper tabs. Once a strain gauge has been affixed to the item to be measured, the p.c.b. should be attached close to the gauge and the fine wires soldered to one end of the tabs. Stronger wires can then be soldered to the other pads on the p.c.b., which can then be connected to the main measurement circuit.

Strain gauges must also be "matched" to the metal, i.e. if we are using aluminium then we must use strain gauges designed to be matched to aluminium. This is because the strain gauge will have the same temperature coefficient and will expand at the same rate as the metal if the temperature changes. The most common gauges are matched to steel or aluminium.

A strain gauge is attached to a metal substrate simply by gluing it. The adhesive chosen should ideally be non-elastic (e.g. an epoxy adhesive) otherwise any strain experienced by the metal will be absorbed by the adhesive and the strain gauge will not register any changes.

The small terminal carrier p.c.b. may already be coated with an adhesive backing, so it can be applied nearby, always ensuring that the surface is completely free of grease and dirt. Should the p.c.b. fall away in use, this could eventually cause damage to the strain gauge.

We have already mentioned that the change in resistance, and therefore voltage, is very small and must be amplified 1,000 times or greater. This means that the circuit is susceptible to interference and the wires connecting the gauge to the measurement circuit should be shielded, i.e. coaxial cable should be used. If this is not available then the wires should be twisted together to help cancel any noise. We will offer a practical demonstration of strain gauges in next month's Lab Work.

USING STRAIN GAUGES

As we have seen, the change in resistance is small and if we pass a current through the strain gauge, the resulting voltage change will also be small. We need a high gain amplifier to increase the voltage level to a usable value.

Strain gauges are also temperature sensitive and require some form of temperature compensation. However, we can use a *dummy* gauge placed close to the active gauge in such a way as to be insensitive to the forces (see Fig.4.15).

The two gauges are placed in a bridge circuit as shown in Fig.4.16. Any changes in temperature will be cancelled out. We can also increase the sensitivity in some applications.

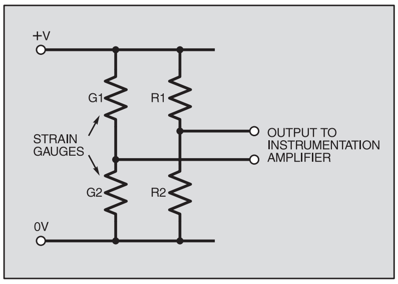
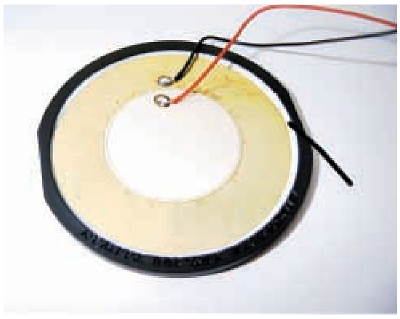


Fig.4.16. Strain gauge circuit.

In next month's Lab Work we show how to build a crude weighing machine based on the bending of a metal bar where a gauge placed on the top will experience tension and a second gauge placed underneath will experience compression. Using these in a bridge will effectively give twice the output voltage, whilst also providing temperature compensation.



Example of a simple piezo disc sounder.

PIEZOELECTRIC MATERIALS AND SENSORS

Piezoelectric material produces a voltage if it experiences a force and also bends if a voltage is applied. This is the basis for all crystals (as used in oscillators) and also for piezoelectric sounders.

A crystal and a piezo-sounder have similar construction – a thin slice of piezoelectric material placed between two conducting plates forming a capacitor. If we apply a force to one plate, we get a transient voltage produced across the plates, and conversely if we apply a voltage across the plates, the plates will bend.

A sounder operates by applying a rapidly alternating voltage. This causes the plates to bend backwards and forwards, moving the air adjacent to the plates and producing a sound. Each sounder will have a resonant frequency at which the output sound level is much stronger.

This resonance is used in crystal circuits to produce highly stable and accurate frequencies. The magnitude of the piezoelectric effect varies depending on the material used. One of the best is lead zirconium titanate (PZT).

Another piezoelectric device is known as a **bimorph** which consists of two layers of piezoelectric material separated by a thin layer and with electrodes on the outside layers. If an electric field is applied across

the electrodes, the bimorph will bend in a similar way to a bimetallic strip in a thermostat. The bimorph will bend in the opposite way if the field is reversed.

Similarly, it will generate a voltage if it is bent and can be used as a vibration sensor. Inexpensive bimorph elements that are readily available are 15mm long, 2mm wide and less than 1mm thick. They make very good vibration sensors but are fragile and can break easily.

BIMORPHS IN ADAPTIVE OPTICS

We have all heard of the Hubble Space Telescope which is in orbit around the earth and seen the spectacular images it produces. The reason for it being above the atmosphere is that it is immune from atmospheric effects such as diffraction and turbulence.

Recently, large telescopes have been built that use a new technique known as **adaptive optics** which attempts to remove these effects by continuously deforming the mirror by small amounts. This could be done by solenoids but their reaction time is long they and cannot operate at high speeds. Bimorph elements can and have been used successfully in this application.

There are some other very interesting applications of bimorphs which include miniature actuators for tiny robots (walking legs) and developing cochlear implants for deaf people where the bimorph converts electrical energy from a microphone into movement within the ear. Bimorphs are also used when precise very small (micrometres) movements are needed for positioning.

PIEZOELECTRIC CHEMICAL SENSORS

One of the most unusual applications of piezoelectric material is to sense gaseous chemicals such as carbon dioxide and sulphur dioxide. These sensors rely on the fact that thin slices of piezoelectric material will have a resonant frequency depending on the area of the slice and its thickness, which is the principle behind crystals as used for timing purposes in oscillators.

If a crystal's enclosure is cut open, a circle of material with electrodes deposited on either side will be seen. This construction is turned into a chemical sensor by placing a thin layer of a chemical on one side of the crystal that will react with, or absorb the chemical we are looking for. If the measurand (substance to be measured) is absorbed onto the crystal, the crystal's mass will increase and its resonant frequency will drop.

Similarly, if the chemicals react, again the mass and frequency will change. Such sensors can be very sensitive and are capable of measuring in parts per billion (1,000 million) (micrograms) but suffer from one major drawback – the reaction may not be reversible, i.e. the sensor can only be used once, or until all the chemicals have reacted.

There are many other sensors capable of measuring forces (such as force sensing resistors) but in this part of *Teach-In* we are only looking at piezoelectric sensors and strain gauges. In Lab Work we show how we can use commonly available piezoelectric sounders to measure forces such as vibration, by building a novel rain detector and a doorbell that is activated by knocking on the door three times!

We will also be looking in future instalments at other sensors that use strain gauges and piezoelectric materials such as pressure sensors.

TEACH-IN 2002 – Lab Work 4

ALAN WINSTANLEY

Detecting Vibrations

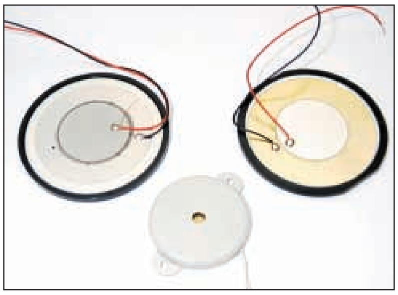
LOUDSPEAKERS rely for their principle of operation on the fact that applying a signal voltage across them produces a movement in the speaker "cone" or diaphragm. This causes an air displacement that, depending on its frequency, is detectable as a sound wave by the ear. Different types of loudspeaker are designed to cope with high frequencies (tweeters), or the "long throw" needed for bass notes (woofers) or frequencies somewhere in the middle (mid-range loudspeakers).

Compare this with the principle of the microphone: it is in effect a loudspeaker in reverse: sound waves impinge on the microphone diaphragm or element, which could be a crystal, a static-charged electret membrane or a "dynamic" moving coil. The movement of the microphone element consequently generates a voltage across the microphone's terminals that can then be amplified.

This month's practical Labs use a form of loudspeaker (or sounder) as an effective electronic method for detecting vibration. We provide a couple of application circuits that could readily be adapted to other applications including monitoring and security applications.

A simple piezo disc element can be utilised as a form of microphone, which will generate a tiny voltage when it detects an impact, vibration or other pressure wave.

Two types of piezo sounder are readily available. A simple piezoelectric disc is nothing more than the sound element itself. To utilise one as a sounder or alarm tone generator, a separate oscillator driver circuit is necessary. It should not to be confused with a self-contained piezo sounder which already has the necessary tone generator incorporated into a plastic enclosure and, therefore, only a supply voltage is required.



Examples of piezo sounder elements. The outer two need an external oscillating signal. The centre one is self-contained with its own oscillator circuit.

The efficiency of modern piezo alarms is extremely high, characterised by high output levels for a relatively low power consumption; even some small units can create ear-splitting sounds.

For the following Labs, we will be using a plain piezo disc which does not have a tone generator.

Lab 4.1 Rain Intensity Meter

It is easy enough to detect the presence of rain, and even the amount of rainfall, but how about discriminating between a light shower and a torrential downpour? A good way of doing this is to sense the impact of the raindrops themselves.

Lab 4.1 will detect such vibration or a series of impacts, and it produces a d.c. voltage that is proportional to the intensity of the raindrops. A heavy shower outputs a higher voltage. It is extremely sensitive and the circuit lends itself for use in other applications.

We rely on the impact of rain drops on a piezoelectric disc (which is actually affixed underneath a plastic or metal plate) to produce a short voltage pulse. Fig.4.17 shows the complete circuit, which consists of two op.amps, the first of which, IC1a, acts as a non-inverting amplifier with a gain between 3·5 and 15·5. This can be set by VR1 to allow different sounders to be accommodated.

The output of IC1a is connected to a peak detector circuit built around diode D1, resistor R4, preset VR2 and capacitor C1. This is a basic form of sample and hold circuit and its operation is straightforward.

Imagine a positive pulse being generated by IC1a, therefore diode D1 will be forward biased and so capacitor C1 will charge rapidly to the voltage of the pulse (minus 0·6V for the diode forward voltage drop). After the amplifier pulse has

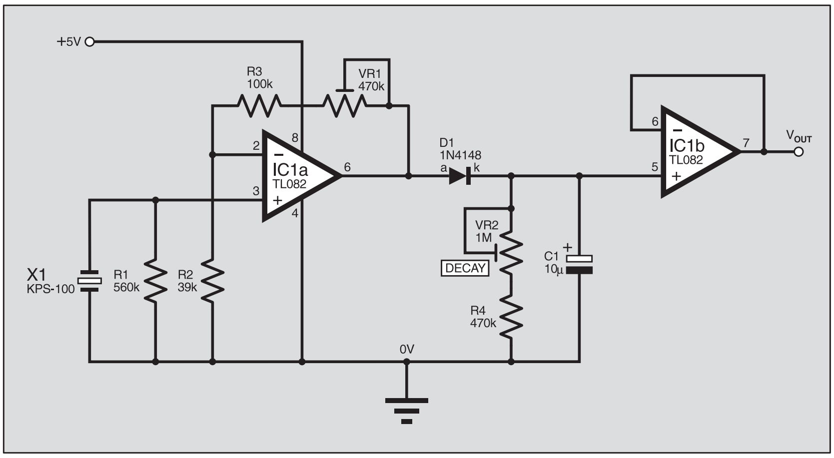


Fig.4.17. Complete circuit diagram for the piezo-disc rain sensor.

returned to zero, the voltage on the capacitor will slowly fall as it discharges to 0V through R4 and VR2.

The time taken to fall will depend on the setting of VR2 and can be varied from approximately 5 seconds to 15 seconds. The period can be made longer by increasing the value of C1, to suit other applications. Multiple pulses caused by rainfall will keep the capacitor charged and the voltage will remain at a given level.

The second op.amp, IC1b, acts as a unity gain buffer to ensure the peak detector circuit is not unduly loaded.

The output of the circuit is a d.c. voltage that represents the intensity of the rain, but the principle is quite crude since many light drops of rain or a single heavy drop may give the same reading. Also, since the piezoelectric sounder is in effect a capacitor, it will take time to respond and at very high rainfall rate the output of the sounder will be continuous.

This circuit is therefore only a simple indicator of rainfall rate, but could easily be expanded to make a comprehensive detector and logger, especially if the output is connected to an input of a microcontroller such as a PIC.

The circuit is straightforward to build on a solderless breadboard. It can be powered using the *Teach-In 2000* power supply to provide 5V d.c. For convenience, a TL082 was utilised in our experiments, but you could try any dual FET input type.

Different sounders have been tried and the best seems to be a large area sounder, such as the KPS-100 piezoelectric sounder. Virtually any sounder will work however, but remember to use a "naked" piezoelectric disc and not a self-contained buzzer.

Use trimmer preset VR1 to adjust for sensitivity and VR2 to control the decay of the signal.

PICOSCOPING VIBRATIONS

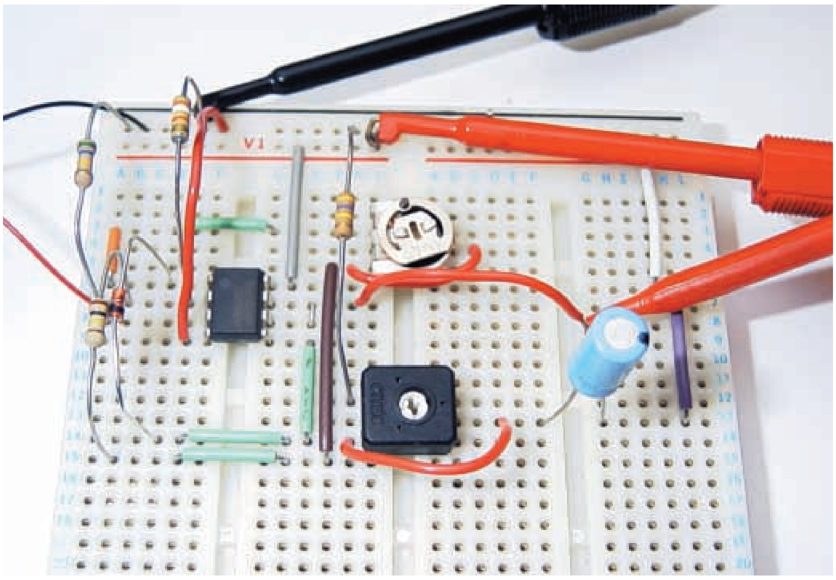
The Picoscope ADC-40 can be used to measure the output directly at pin 7 of IC1b. Select a relatively slow timebase, e.g. five seconds per division. You can demonstrate this by directly inserting the leadouts of the piezo disc into the breadboard and resting the disc on the tabletop.

By experimenting with the gain, we found the circuit would easily register a finger tapping the tabletop or fingers drumming nearby. The screenshots (next page) show the Picoscope waveforms measured during the experiment. Notice how the voltage rose and decayed slowly as the rate of impacts changed.

You could try connecting the output to the Picoscope data logger and log the intensity of rainfall over, say 24 hours. Only allow the sensor to be impacted by rain, everything else must be kept absolutely dry.

If you decide to build the circuit into a working project, we suggest gluing the sounder to the back of a plastic or a metal box to increase the surface area and increase the chances of capturing raindrops. The box should be placed at a slight angle to allow rain to flow off the surface.

It is also a neat idea to place the circuit inside the box to form a completely



Breadboard assembly for the circuit in Fig.4.17. The sensor is not shown, but its leads can be seen at the top left.

COMPONENTS

N.B. some components are repeated between Lab Works

See SHOP TALK page

Lab 4.1

Resistors

R1	560k
R2	39k
R3	100k
R4	470k

All 0·25W 5% carbon film.

Potentiometers

VR1	470k sub-min preset, horiz
VR2	1M sub-min preset, horiz

Capacitor

C1	10µ radial elect. 16V

Semiconductors

D1	1N4148 silicon diode
IC1	TL082 or similar dual op.amp

Miscellaneous

X1	KPS-100 50mm piezo-electric speaker

Lab 4.2

Resistors

R1	560k
R2	39k
R3	470k
R4	39k
R5	4M7
R6	3M3
R7	56k

Capacitors

C1	1n to 100n ceramic (see text)
C2, C3	1µ tantalum or radial elect. 16V (2 off)

Semiconductors

IC1	OP177, CA3140 or similar FET input op.amp
IC2	4093 quad Schmitt trigger NAND gate
IC3	4520 dual counter/divider
IC4	4098 dual monostable

Miscellaneous

X1, X2	KPS-100 piezoelectric speaker (2 off)

Approx. Cost Guidance Only **£14**

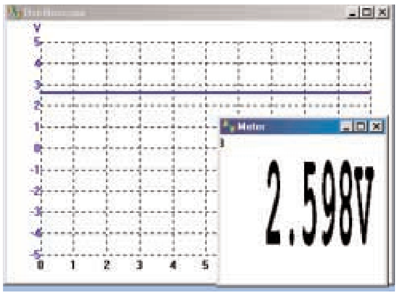
self-contained vibration or impact sensor, preferably using coaxial cable to connect to other control circuitry as required. Use silicone sealant to seal any cable exits.

Can you think of any further applications for a completely solid-state, self-contained impact detector? How about a burglar alarm that detects an impact on glass, doors or floors? By setting the sample and hold component values accordingly, you could cater for false alarms caused by minor impacts. Perhaps it could be incorporated into vehicle alarms as well.

More experienced readers will be able to add on a variety of simple circuits, perhaps based on a Schmitt trigger or a thyristor, that could be triggered by the output voltage of IC1b.

Lab Work 4.2 – Door Knocker Circuit

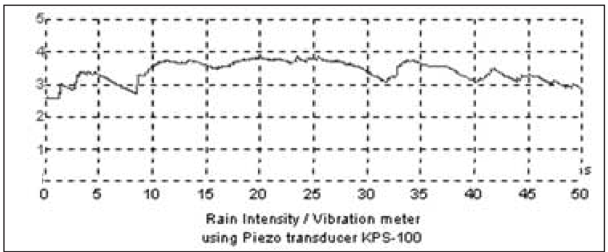
The circuit for Lab 4.2 is a bit of fun but could be incorporated into a novel doorbell which is activated by a number of knocks (say three) on the door. Fig.4.18 shows the circuit diagram and the first thing to notice is that the "knock" sensor based around op.amp IC1 is virtually the same as the sensor for rain intensity described in the previous experiment.



"Smoothed" rainfall monitored at IC1b.

The only difference is that the gain is fixed at about ×13 to ensure we get a good pulse out when someone knocks the sounder. There is plenty of scope for experimentation; we tested a variety of different op.amps including the OP177 and the CA3140. The latter has MOSFET inputs and bipolar outputs. Be prepared to experiment with the amplifier gain values to obtain the best results in your own breadboard experiments.

The rest of the circuit may seem complex but it is quite simple to analyse. Fig.4.19 shows the timing diagram which should make the circuit's operation clearer. We start with the output of the amplifier (point A), which is a short pulse when the sounder is knocked. This pulse is made longer (point B) by the low pass filter formed around the RC (resistor-capacitor) network R4 and C1.



Picoscope display of rainfall monitored by the circuit in Fig.4.17 at the output of IC1a.

Gate IC2a is a Schmitt NAND gate connected as an inverter to form a clean pulse (point C). This pulse is input simultaneously into counter IC3 and one half of a 4098 dual monostable, IC4a. The latter is connected as a non-retriggerable monostable by connecting its Q_1 output (pin 6) to its $+TR_2$ input (pin 4). This stops any more pulses restarting the timing pulse.

The Q_1 output of monostable IC4a will be high for two seconds when triggered. The inverted output, $\overline{Q_1}$ (pin 7) is connected to the reset input (RST_1) of counter IC3 to *enable* it for a period of two seconds. The idea here is to count knocks for two seconds only and there must be (say) three knocks or more for the doorbell to be activated.

KNOCK THREE TIMES

Since the counter is disabled for the first knock, it will count to two for three knocks. Between them, gates IC2b and IC2c detect this and the output of IC2c (point D) triggers a second monostable, IC4b, for about one second.

The output of IC4b (pin 10) could be used to activate a relay to sound the doorbell. Here, though, we have illustrated the principle of operation by turning on a piezo sounder (X2) for about a second. NAND gate IC2d is connected as a modest audio oscillator which is enabled by the Q_2 output of IC4b.

An important point to note is the fact that the second monostable will be triggered only if the count is three or four and only when the two second interval has passed. You can, however, vary the values by altering the monostable timing components (R6 and C3) to suit.

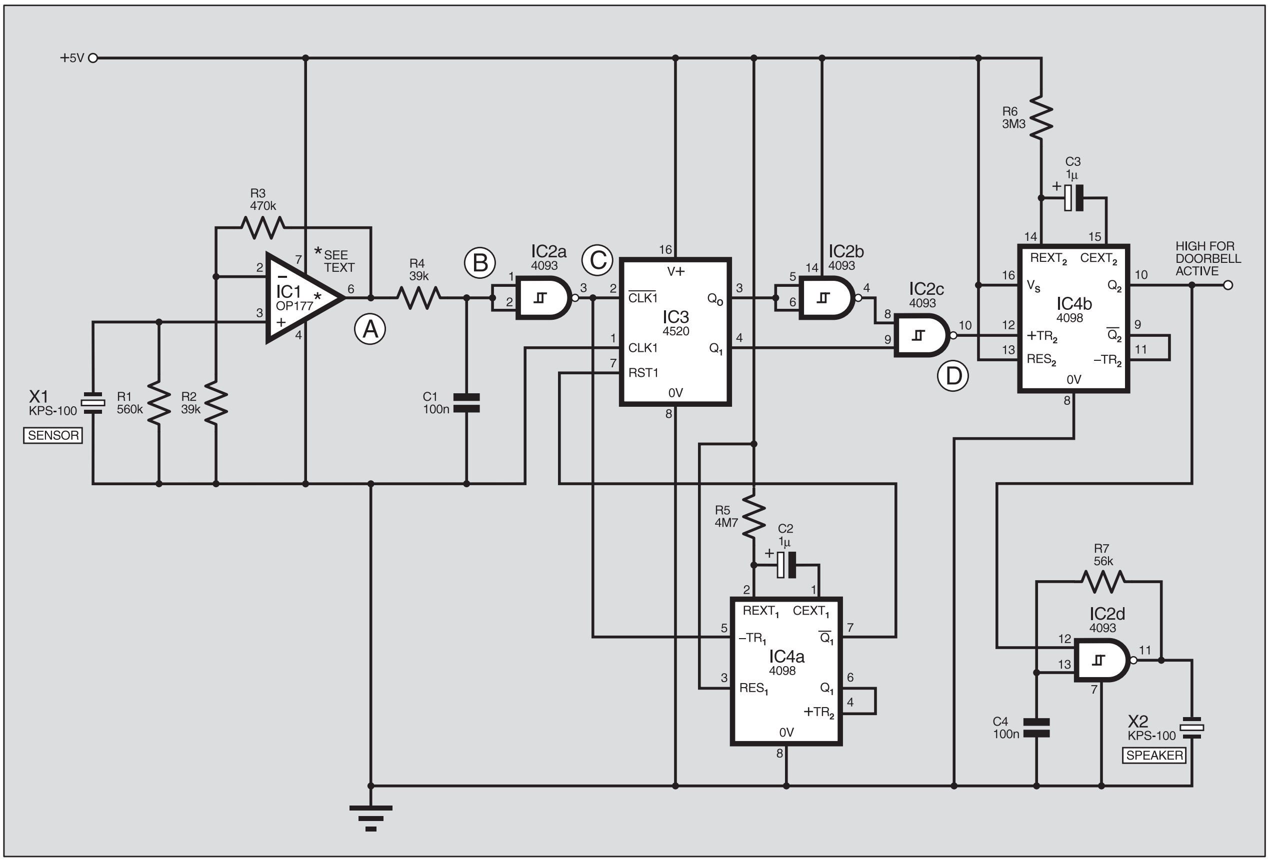


Fig.4.18. Complete circuit diagram for the "knock three times" sensor.

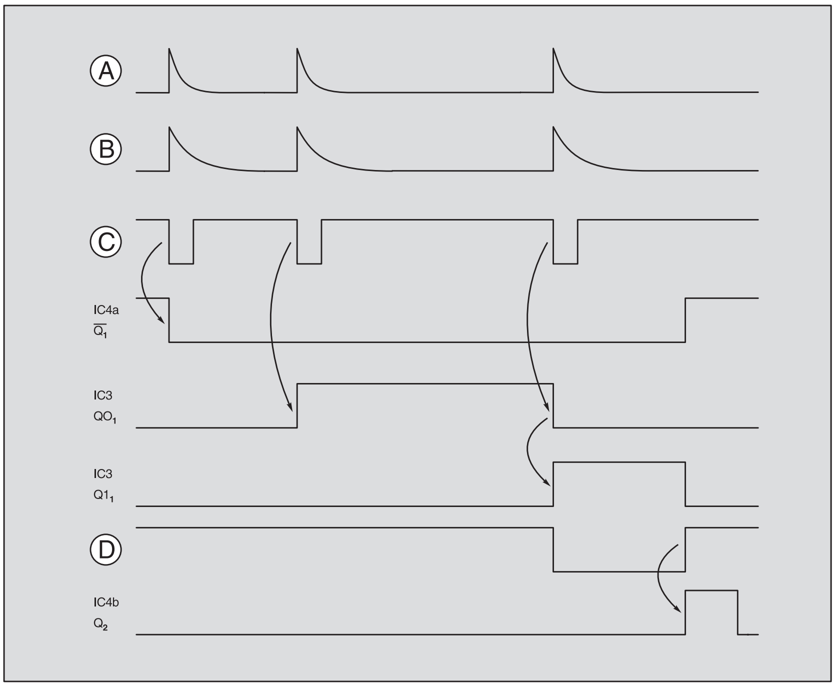
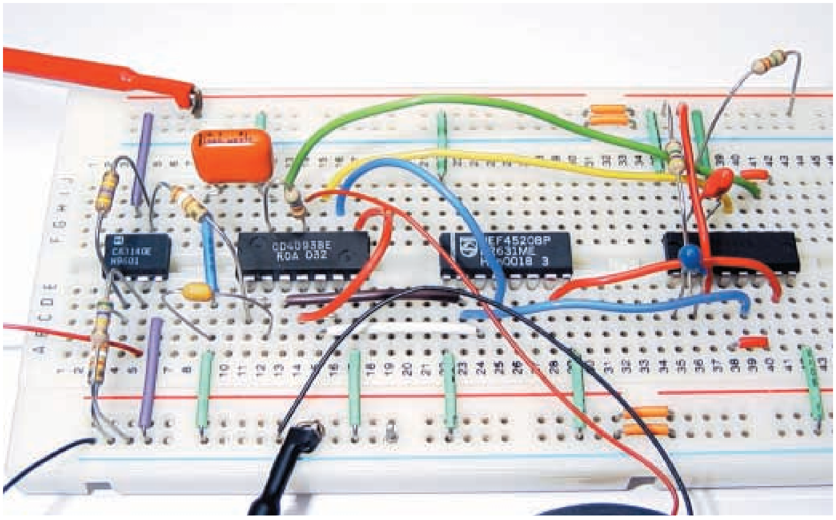
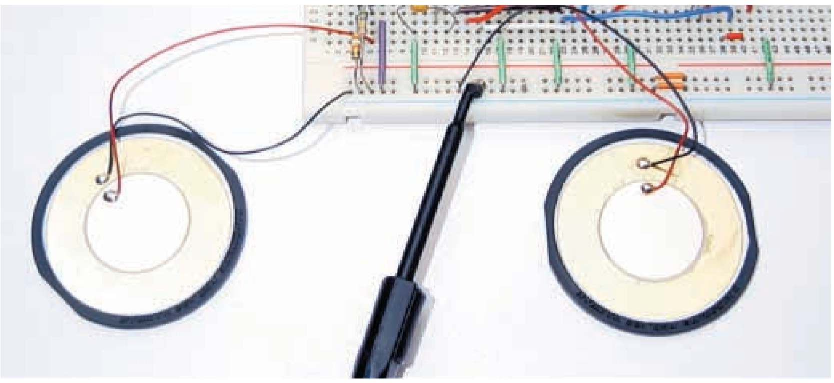


Fig.4.19. Timing waveforms for the circuit in Fig.4.18.



Above: Breadboard layout for the circuit in Fig.4.18. Below: Sensors connected to the above layout.



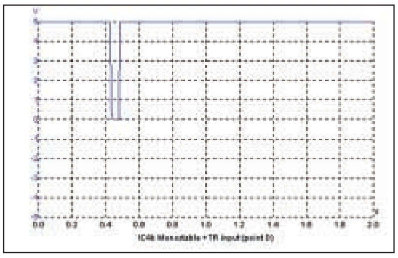
It is relatively straightforward to build this circuit on a long solderless breadboard, provided you work methodically through the circuit. Use fine long-nose pliers as necessary to help insert wires.

A pair of KPS-100 piezoelectric sounders were used both for the knock sensor and the sound element, with both elements resting on the table alongside the breadboard. It was found that by giving the table several sharp raps in succession underneath the piezo disc "microphone", the sounder operated for a short period.

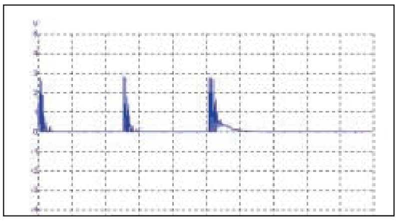
Do, however, be prepared to experiment with the amplifier, as this is the most critical aspect in ensuring that the circuit functions successfully. If necessary, monitor the circuit with a logic probe or your Picoscope to check what happens when the piezo disc X1 is subject to a tap nearby. (It is best not to knock the quite delicate piezo element itself.)

The best approach to practical design is to put the outdoor knock sensor behind a plate which has the words on it – "Knock here 3 times to ring the doorbell". We are sure there are many other applications of this simple circuit, such as detecting something thrown at it – you could make a throwing game similar to a coconut shy and ring bells or turn on lights if a ball hits the "coconut".

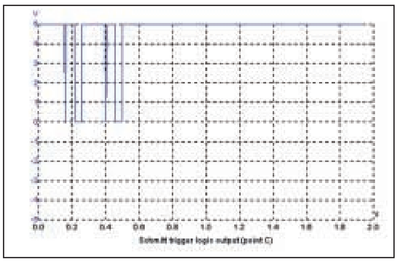
We hope you enjoyed learning about some more unusual uses for piezoelectric elements. With a more serious application in mind, the circuit values could readily be adapted to warn of a series of impacts or excessive vibrations, e.g. to detect a break-in, as the need to have a rapid succession of impacts before the sounder is triggered may help prevent false alarms.



Single "knock" waveform at Fig.4.18 point D.



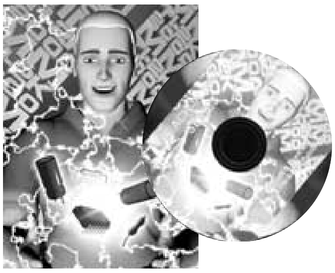
Triple "knock" waveform at Fig.4.18 point A.



Multiple "knock" waveform at Fig.4.18 point C.

NEXT MONTH

Next month we offer a sensitive strain gauge circuit which uses some of the principles outlined in this tutorial section. We will also be moving on to describe instrumentation amplifiers, and in forthcoming parts we will be investigating the principles behind the detection of acceleration and pressure.



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Circuits include: High impedance mic preamp, Low impedance mic preamp, Crystal mic preamp, Guitar and GP preamplifier, Scratch and rumble filter, RIAA preamplifier, Tape preamplifier, Audio limiter, Bass and treble tone controls, Loudness filter, Loudness control, Simple graphic equaliser, Basic audio mixer, Small (300mW) audio power amp, 6 watt audio power amp, 20/32 watt power amp and power supply, Dynamic noise limiter.

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A. Flind
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The topics covered in this book include: the basic concepts of logic circuits; the functions of gates, inverters and other logic "building blocks"; CMOS logic i.c. characteristics, and their advantages in practical circuit design; oscillators and monostables (timers); flip/flops, binary dividers and binary counters; decade counters and display drivers.

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AUDIO AND MUSIC

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Along with the electric guitar, sections are also included relating to acoustic instruments. The function of specialised piezoelectric pickups is explained and there are detailed instructions on how to make your own contact and bridge transducers. The projects range from simple preamps and tone boosters, to complete active controls and equaliser units.

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This book allows those with a limited knowledge of the field to understand both the theory and practice of valve audio amplifier design, such that they can analyse and modify circuits, and build or restore an amplifier. Design principles and construction techniques are provided so readers can devise and build from scratch, designs that actually work.

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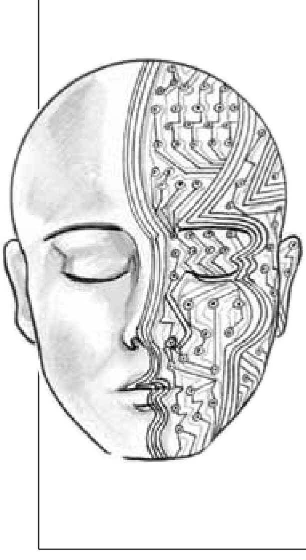

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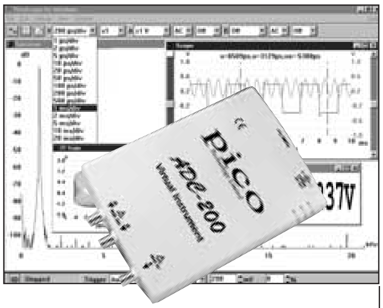

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Smart Alarm Timer – Dual Standards

When designing a timing circuit for a security alarm, one often has to face a compromise between functionality and circuit complexity. The Smart Alarm Timer circuit described in Fig.1, however, is a complete solution featuring an entry delay, a finite alarm time and protection against multiple triggering.

It utilises a standard 556 dual timer i.c. configured as two separate monostables, one with a much shorter time period than the other. The trigger inputs are tied together to give the timing diagram shown in Fig.2.

It can be seen from Fig.2 that the potential difference between the two timer outputs is similar to the alarm signal required. Since the output stages of the 556 are capable of both sourcing and sinking current, a piezo siren WD1 (see Fig.1) can be connected simply between the two timer outputs, pins 5 and 9. Although the drive capacity is limited to 200mA, very loud multi-element piezo sirens are available which consume in the region of only 40mA.

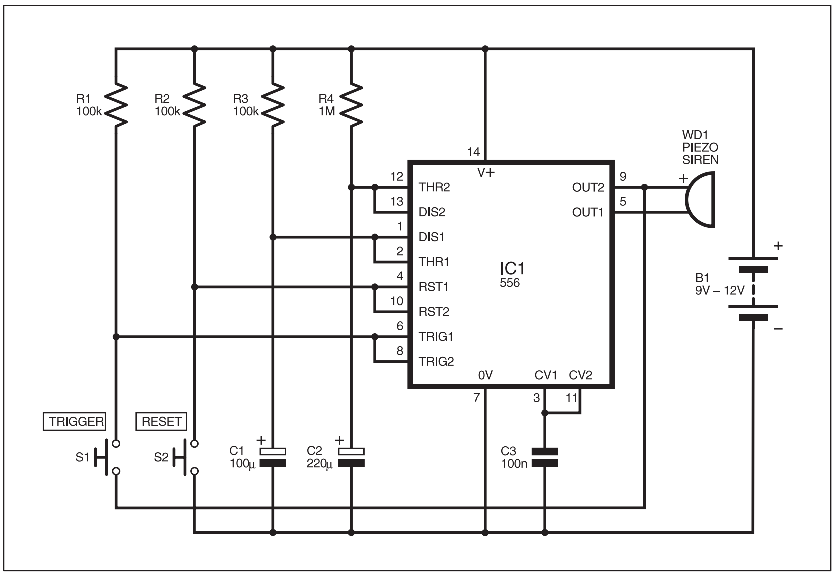

Fig.1. Circuit diagram for the Smart Alarm Timer.

Delayed Entry

As the circuit uses the standard 555 monostable mode of operation, the constructor can choose the values of resistor R3 and capacitor C1 to set the entry delay, and R4 and C2 to set the total alarm time (including entry delay). Low leakage tantalum capacitors for C1 and C2 will help improve accuracy.

Variable resistors (potentiometers) could be substituted for R3 and R4 (with 1 kilohms resistors in series to provide a minimum resistance) allowing the time delays to be set "in the field". The values shown gave an entry delay of about 12 seconds and an alarm time of about 5 minutes.

The normally-open Trigger switch S1 is connected slightly differently from normal, using the output of the long period timer to give the 0V potential required to trigger the timers. This feedback allows the circuit to trigger as normal, but it is non-resettable, i.e. after triggering it blocks any further input until the timing cycle is complete.

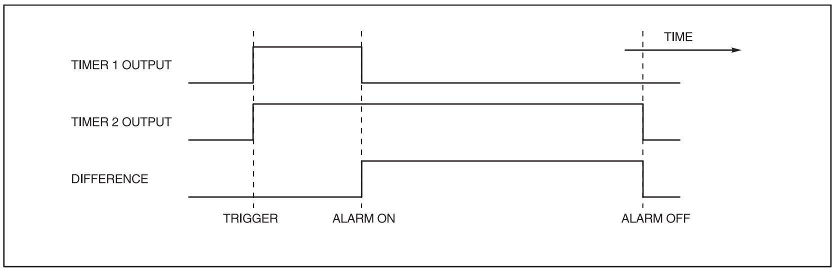

Fig.2. Circuit timing diagram.

The Reset switch S2, however, can be used to interrupt the cycle at any stage. You could use a keyswitch for this component.

Ben Weaver,
James College, University of York.

MORE CIRCUIT IDEAS

L.E.D. Dynamo Torch – Power to Your Elbow

HAVING purchased a cheap Dynotorch, the author found that its 2·4V filament bulb was hard work, needing a lot of continuous hard hand squeezes to give any useful light. It was decided, therefore, to convert it into a more efficient l.e.d. torch that could be illuminated readily by squeezing the "dynamo lever". A number of bright yellow l.e.d.s were to be utilised as they are good for reading and for night use, e.g. camping.

Much experimentation revealed that driving a load of 68 ohms, the Dynotorch gave 5V to 6V a.c. but trying to utilise this with a regulator i.c. meant the torch was very hard work. A constant-current circuit was therefore developed using a current booster circuit.

The resulting circuit diagram is shown in Fig.3. This is centred around IC1, an LM334 constant current source with transistor TR1 acting as an external current amplifier. The Schottky diodes D1 to D4 form a bridge rectifier with low drop-out voltage, and the Zener diodes D5, D6 clamp the voltage to eliminate spikes. The optional electrolytic capacitor C2 smooths the resultant d.c. supply.

The current through the l.e.d.s is measured by feeding the voltage across the resistor array R2 to R5 into IC1, whose positive supply is taken from the base of TR1. Hence, IC1 draws whatever current (TR1 base current) is necessary to give the correct current through the l.e.d.s. It was also found that due to the high efficiency of the l.e.d.s, the momentum of the dynamo rotor acted as a flywheel which helped to greatly reduce the effort needed to obtain a useful light.

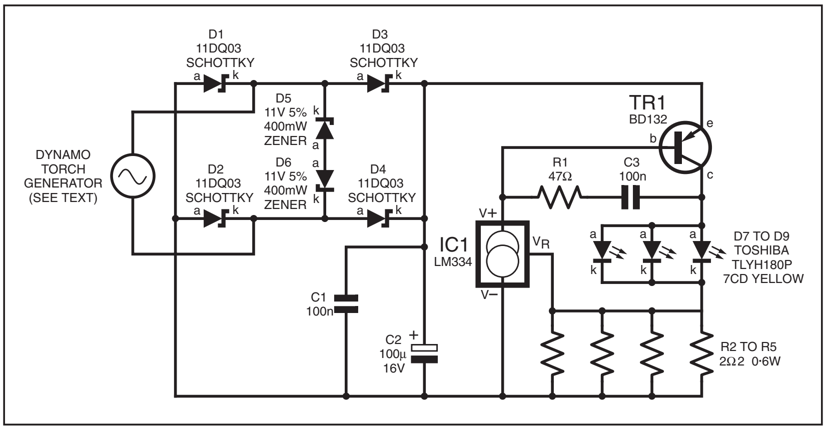

Fig.3. Circuit diagram for a L.E.D. Dynamo Torch.

The circuit was built on a hexagonal piece of stripboard which, with the silver lamp reflector removed, fitted into the torch and was secured with Blu-Tak. If you dismantle the torch it is best not to remove the magnetic rotor from its metal armature for very long. Gears can be lubricated with a silicone-based grease suitable for plastics.

Alan Bradley,
Belfast, Northern Ireland

Walkman in a Car – Music On The Move

THE circuit diagram of Fig.4 came to life when the writer's car cassette chewed up another of his best tapes. Rather than replace the in-car unit with an upmarket (and thievable) system, it was decided to use a Walkman-type cassette player – a good, reliable tape transport system which was easy to remove to safety.

It could be coupled to the car player with a CD tape adaptor unit but not without problems: most Walkman-types run on 3V and the car voltage can be anything from 10V to 15V. The simple circuit diagram shown in Fig.4 produces a stable 3V d.c. supply from a car's electrical supply which can power a Walkman-style player.

A configuration using a series pass transistor would require a heatsink to dissipate the wasted power (10V × 0·5A = 5W). A far more efficient way needing no heatsink is to use a switching regulator such as the TL497. Only a few components are needed to create a neat DC/DC voltage converter, the output voltage of which is set by multiturn preset VR1.

In practice the circuit seems to be able to cope with the demands of the Walkman very well, and the TL497 just gets slightly warm. To be sure that all is well, run the player through its functions using a voltmeter on the d.c. output. The only time the circuit seems to struggle is during fast forward/rewind and tape direction changeover, but for general playing the circuit is most acceptable.

A word of warning – a fair amount of shielding and decoupling will be needed if you want to use the Walkman radio section as the circuit is responsible for some nice broadband r.f. emissions.

Steve Dellow, Warwick

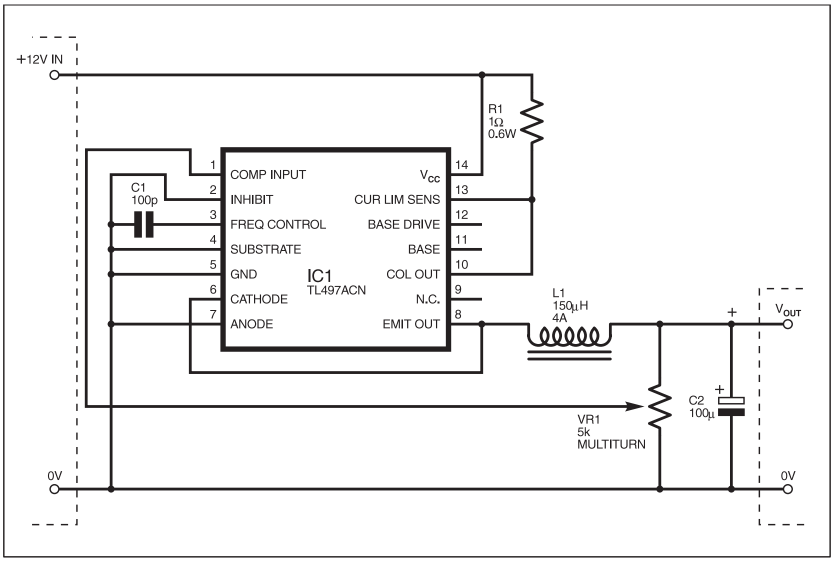

Fig.4. Circuit diagram for an In-Car Power Supply for a "Walkman" type cassette player.

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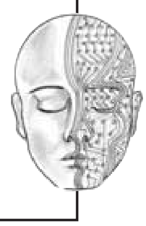

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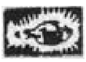

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